Report to

Department of the Army
New England Division
Corps of Engineers

on

Contract DACW33-81-C-0016

Environmental Baseline Data Collections and Site Evaluations, Long Island Sound Container Disposal Study Black Ledge, Groton-New London Harbor, Connecticut

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407-389

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Environmental Baseline Data Collections
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Black Ledge, Groton-New London Harbor, Connecticut

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March 1982

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Contents

List of Tables

List of Figures

1.0. INTRODUCTION

1.1. Background

The Groton-New London Harbor area is one of several locations in Long Island Sound being considered for construction of a dredged material containment facility (DMCF). A DMCF is a structure designed to contain dredged material and prevent its transport away from the containment site with consequent reentry into the natural ecosystem. Although DMCFs are particularly valuable in the case of contaminated or toxic spoils, they also have application for relatively clean materials which could otherwise cause environmental degradation through, for example, smothering, sediment alteration, and increased turbidity. Properly designed and constructed DMCFs have the potential of being an environmental enhancement in certain areas through the creation of desirable habitat types.

The work reported herein was contracted by the New England Division, Corps of Engineers (NED/CE) as part of the Long Island Sound Dredged Material Containment Study, a multi-phased program to examine the feasibility of the containment alternative, assess economic and social impacts, screen potential DMCF sites, and perform environmental baseline field surveys and assessments. The purpose of this study is directed toward the latter two objectives.

The proposed DMCF site at Groton-New London, shown in Figure 1, is located approximately one mile outside of the entrance to New London Harbor, to the east of the harbor entrance channel. The site comprises a rocky shoal area known as Black Ledge where water depths rise rapidly from the surrounding 20'-30' (MLW) to less than 10' over much of the shoal. A small pile of rocks approximately $10m^2$ near the western limit of the ledge is exposed at most tidal elevations. The total area of the shoal (depths within the 18' isobath) is approximately $320{,}000m^2$, or about .1 square mile.

The Black Ledge site was recommended by the City of Groton Conservation Commission and Harbor Study Commission. The area is reported to be a navigational hazard to recreational boating and of minimal value for fishing and lobstering. Proposed benefits of a DMCF

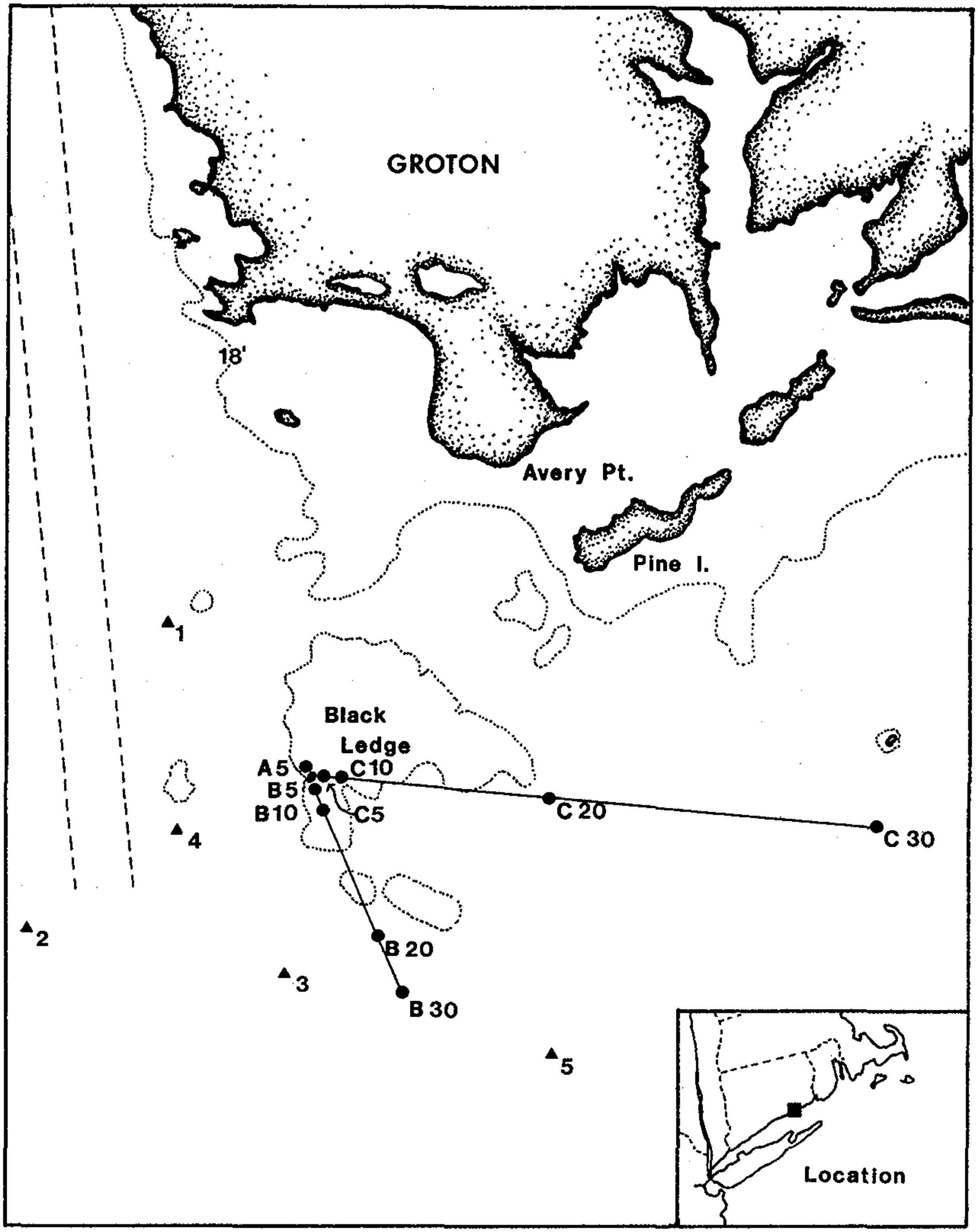

Figure 1: Black Ledge Project study area location, showing extent of ledge (18' isobath), relationship to shoreline and harbor channel, and stations sampled.

island at the site include the establishment of a preserve for controlled ecological studies and storm protection for the southern shore of the City of Groton.

1.2. Study Objectives and Organization

The purpose of this study was to provide preliminary environmental baseline information on the biotic communities both at Black Ledge and in the immediate environs. Primary emphasis was placed on the benthic macrofauna since this group would be most directly impacted by DMCF construction. An evaluation of the present habitat was needed in order to compare the potential habitat value of the DMCF with the value of the natural area.

In order to meet these objectives, Taxon designed a sampling plan comprising diver-operated suction sampling and traditional grab sampling. Taxon was responsible for the collection and processing of all macrofaunal and macroalgal materials. In order to develop information on the habitat value of soft-substrata in the Black Ledge vicinity, a subcontract was let to Marine Surveys, Inc. (MSI), New Haven, CT, who conducted a REMOTS^{TM} survey at deeper stations to the south and west of the shoal. The results of the two survey techniques are fully integrated into this report, however, the complete MSI report is included as Appendix 1.

2.0. METHODS

2.1. Sampling Plan

The location of all stations sampled is shown in Figures 1 and 2 and the bearings and landmarks used to determine position are provided in Appendix 2. The diver sampling of rocky bottoms was conducted along three transects (A,B,C) with samples to be taken at 5', 10', 20' and 30' on each transect, respectively. The original sampling plan included six transects for a total of 24 stations; subsequent problems with equipment and weather allowed the collection of samples from only nine stations, as shown in Figure 2.

In addition to the transect stations, five additional stations were established in areas which were expected to have soft substratum. These

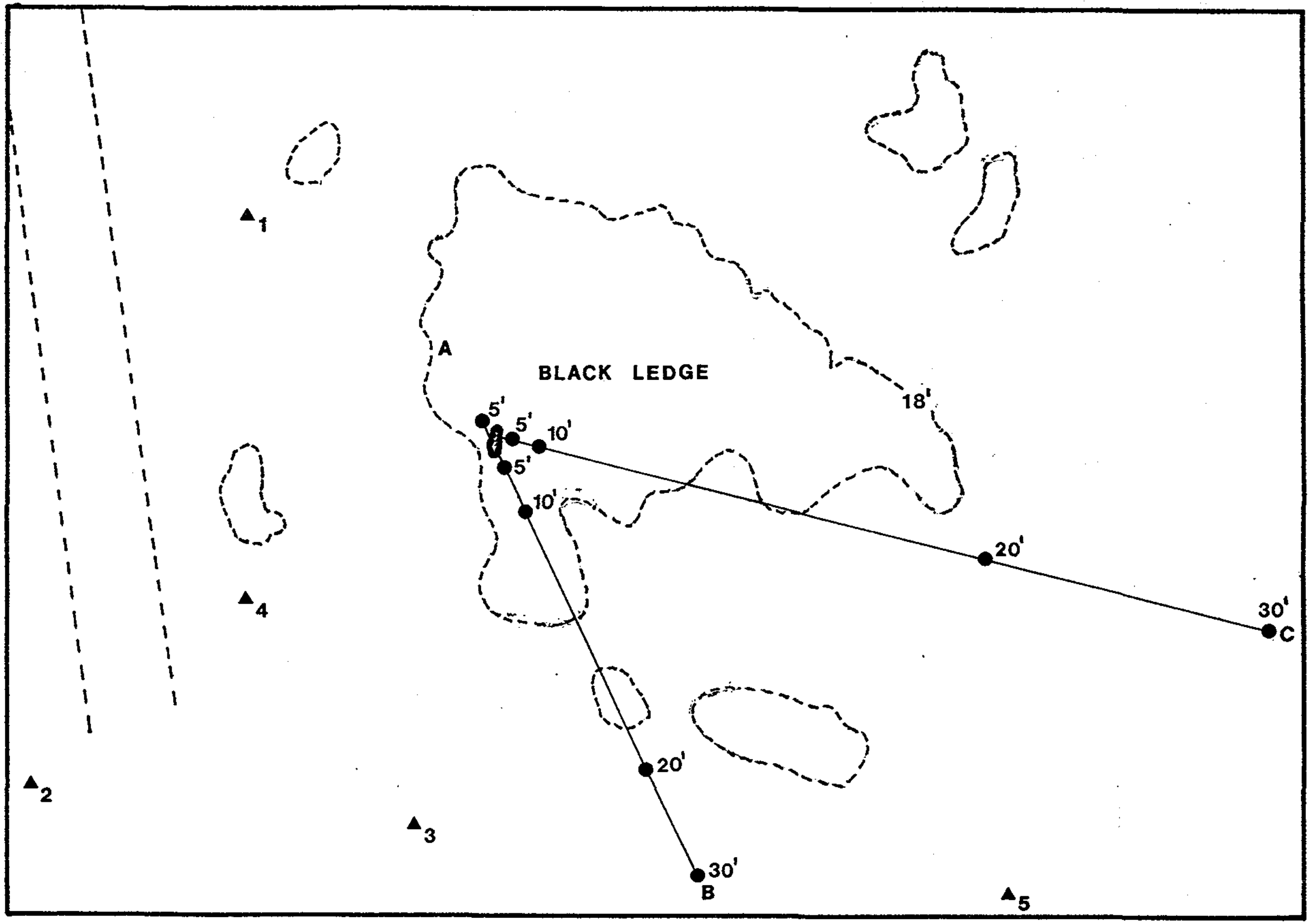

Figure 2: Detail of Black Ledge Project station locations.

stations were located primarily to the west and south of the shoal. At these stations, macrofaunal samples were collected by grab and sediment-water interface (REMOTS) imagery was obtained.

2.2. Sample Collection

The five soft-bottom stations were sampled on 31 August 1982; macrofaunal sampling and REMOTS photography were conducted simultaneously to ensure consistency of station location. Two replicate samples were collected at each station with a $0.04m^2$ modified VanVeen grab. All samples were immediately sieved at 0.5mm through a stainless-steel sieve and fixed in 10% buffered seawater formalin. An aliquot for sediment grain-size analysis was removed from each grab prior to sieving. MSI obtained up to six replicate sediment profile images per station at Stations 1 - 4; the nature of the substratum at Station 5 did not permit REMOTS imagery.

SCUBA sampling of transect stations was conducted on 16 October and 3 November 1981. At each of the deeper stations, sampling was first attempted with the grab sampler. If sufficient penetration was obtained, no diver samples were collected. When sampling by grab was not possible, a team of divers collected two replicate samples using a $0.1m^2$ pipe-frame quadrat and air-lift suction device fitted with a 0.5mm mesh Nitex bag (Figure 3). At stations with gravel substratum, the bottom within the quadrat was excavated with the air-lift to a depth of 10cm; at rock stations, all algal and faunal material within the quadrat was scraped off the rock and suctioned into the collecting bag. All samples were preserved in 10% buffered seawater formalin.

2.3. Laboratory Analysis

All grab samples were washed and transferred to 70% isopropanol prior to processing. Samples were then stained with Rose Bengal to facilitate recognition of macrofauna and separated into basic macrofaunal groups by technicians using low power stereoscopes. Taxonomic identifications were determined by experienced taxonomists using high resolution stereoscopes or compound microscopes, as necessary. Identifications were carried to species level where possible and all species were enumerated.

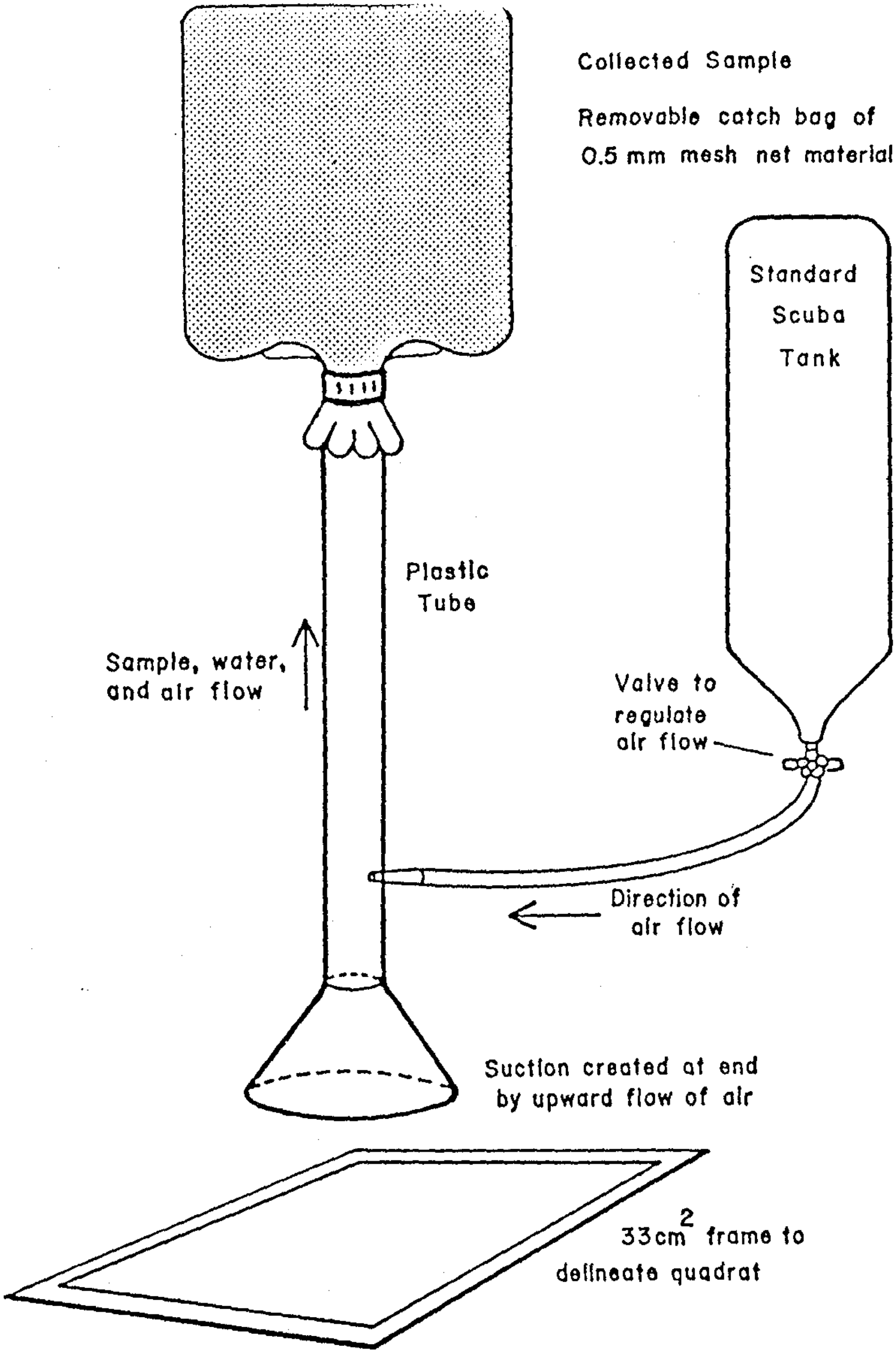

Figure 3: Diagram of diver-operated air-lift rock substratum sampling equipment.

For the diver-collected samples, all material was washed and the algal and faunal fractions were separated; when large numbers of adult Mytilus edulis were present they were removed by hand and counted at this stage. Faunal material was transferred to 70% isopropanol and processed in the same manner as the grab samples. Algal material was transferred to 5% formalin and subsequently identified using stereo and compound microscopes. Algal dominance heirarchies were determined according to frequency of occurrence of each taxon within a sample. Algal biomass was determined by drying the algal fraction at 80°C for 72 hrs. and weighing on an analytical balance. Because the Black Ledge flora comprised exclusively small filamentous forms, separate biomass determinations by taxa could not be performed reliably.

Sediment profile images were measured for: 1) modal grain-size (visual comparison of photos with prepared grain-size standards), 2) camera penetration depth (P), 3) presence of methane gas pockets, 4) aerated sediment (positive redox) area, and 5) faunal successional stage. Variables 3 - 5 were used to generate a habitat index based on the following scaling:

Planimetered Oxidized Area	Index Value
0.1 - 10.0 cm^2	1
10.1 - 20.0 cm^2	2
20.1 - 30.0 cm^2	3
30.1 - 40.0 cm^2	4
40.1 - 50.0 cm^2	5
$>$50.0 cm^2	6

Successional Stage	Index Value
Azoic	-5
Stage 1	1
Stage 1 - 2	2
Stage 2	3
Stage 3 - 4	4

Chemical Parameters	Index Value
Methane present	-2
No/Low dissolved O_2	-4

Sediment grain-size aliquots from the grab samples were analyzed gravimetrically at 1Ø intervals using dry sieving for the coarse fraction ($<$63u) and standard pipette technique for the silt-clay fraction.

All quantitative macrofaunal data were entered directly into the WHOI VAX 11/780 computer from a remote terminal located at Taxon. Classification analysis was performed using programs BMDP1M and BMDP2M of the Biomedical Computer Programs package of the University of California. Computational details are discussed in Section 3.2.3. of this report. Diversity and evenness values for each replicate were calculated on a programmable hand calcualtor.

3.0. RESULTS

3.1. Substratum

Bottom substrata in the Black Ledge vicinity fall into three general categories: rock, sand/gravel, and silt/clay. The distribution of these bottom types in the area sampled is shown in Figure 4, and the grain-size data are summarized in Table 1.

On the ledge, the bottom consists of large angular boulders with generally flat sides; these are evidently not of natural origin, and it was apparent that much of the exposed portion of Black Ledge was transported to the site as rip-rap. The placement of these is such that crevices and small caves are abundant, providing a variety of microhabitats. All of the 5' and 10' transect stations had rock substratum and this bottom type is characteristic of the shallower shoal areas.

Sand/gravel substratum was found at the 20' and 30' transect stations to the east and south of Black Ledge. Station C30 was markedly sandier than the other three and was sampled by grab; thus, grain size data are available. The substratum at C30 was a muddy sand of 0.23mm diameter with approximately 12% silt-clay content. The complete grain-size frequency distribution for all soft-bottom stations is provided in Appendix 3.

Sediments at the grab stations 1 - 4 were silts with substantial (up to 35%) amounts of fine sand. Median grain size at these stations ranged from 0.020mm to 0.028mm and the general pattern of the frequency distributions was similar among the stations. Station 5, to the southwest of the ledge, was intermediate between the sandy

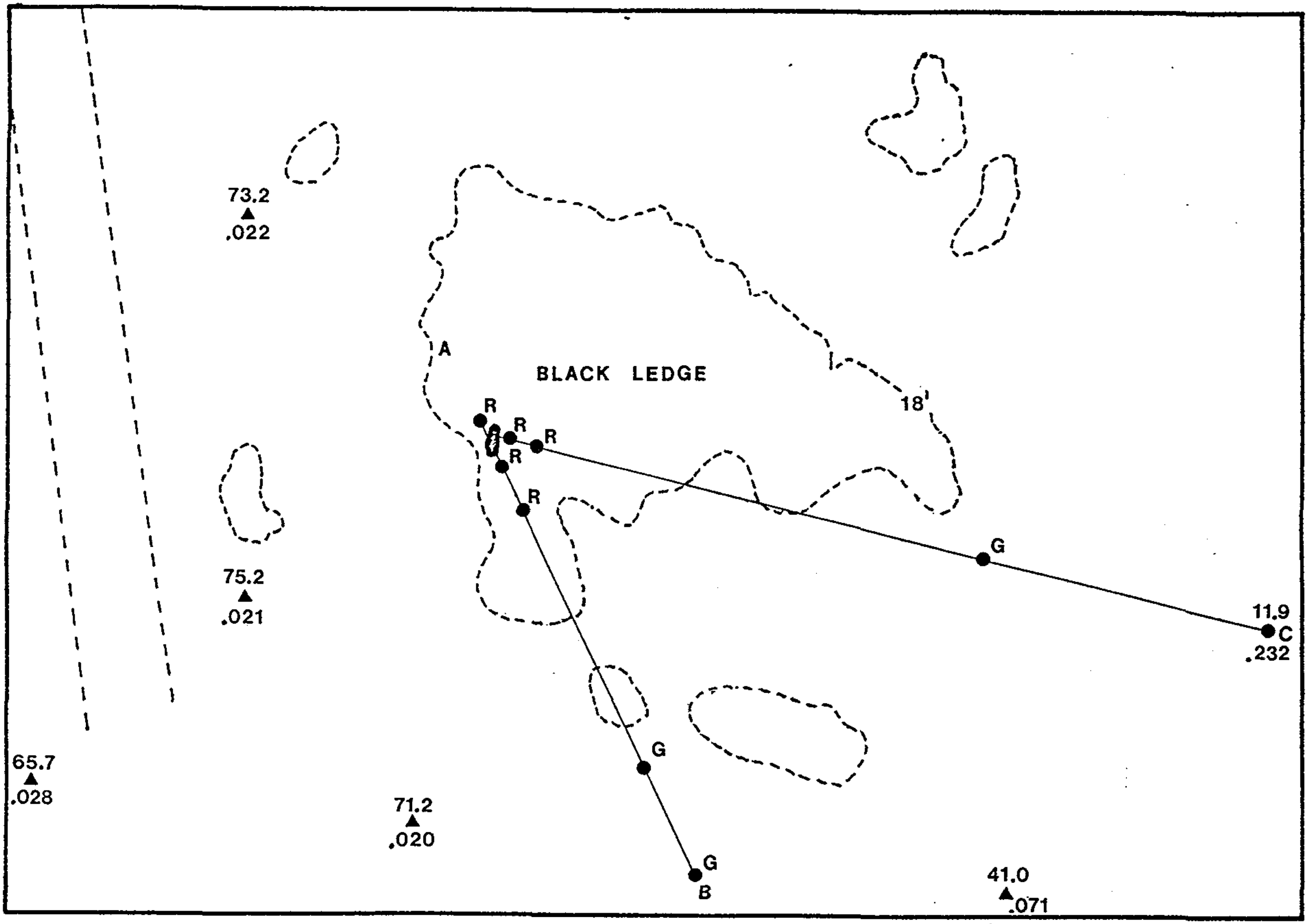

Figure 4: Substratum characteristics: % silt/clay (above station point), median grain size in mm (below station point). For stations which were sampled by divers: R = rock substratum, G = gravel substratum.

Table 1: Summary grain-size frequency distribution parameters for all stations sampled by grab.

Station - Replicate	Median(mm)	Modal Class(Ø)	% Silt-Clay
1-1	.017	4 - 8	79.6
1-2	.027	4 - 8	66.8
2-1	.031	4 - 8	62.7
2-2	.025	4 - 8	68.7
3-1	.021	4 - 8	71.6
3-2	.021	4 - 8	70.9
4-1	.018	4 - 8	78.6
4-2	.022	4 - 8	71.7
5-1	.074	3 - 4	37.8
5-2	.068	3 - 4	44.3
C30-1	.136	3 - 4	14.5
C30-2	.327	1 - 2, 3 - 4(bimodal)	9.3

transect stations and the silts, and had a poorly-sorted substratum of about 40% silt/clay intermixed with fine and some coarse sand.

3.2. Black Ledge Fauna

3.2.1. Species Composition

The list of species or taxa found in the 30 macrofaunal samples collected from Black Ledge is presented in Table 2 and all faunal raw data are included as Appendix 4. The list contains 184 taxa representing all major taxonomic groups. This is an extremely extensive list for the number of samples processed and is indicative of the variety of habitats sampled.

Polychaetes were the dominant faunal group, comprising 76 species, or 41.3% of the total species list. Molluscs and crustaceans were approximately equal in diversity, being represented by 46 (25.0%) and 48 (26.1%), respectively. Amphipods were particularly numerous among the crustaceans; this was related to the extensive algal/mussel mats at the rock stations which provide ideal habitat for a wide variety of amphipod species. This factor was probably also responsible for the extensive inventory of gastropods.

When the extent of the Black Ledge species list is compared with those from some recent surveys of northern Long Island Sound estuaries, the diversity of the area becomes even more striking. In a survey of Black Rock Harbor and Bridgeport Harbor (CEM, 1981) a total list of 123 taxa was reported. That study was much more extensive than the present survey, including two seasonal collections at 64 stations distributed over a much greater area. More recently, in a survey of Clinton Harbor also associated with the potential creation of a DMCF, McGrath et al. (1982) reported 145 taxa from 16 stations which were sampled twice. Hartzband et al. (1979) reported 302 taxa from New Haven Harbor from a very extensive program encompassing two laboratories, nearly 30 stations, and intensive sampling over several years.

3.2.2. Species Richness and Faunal Density

Species richness, faunal density, and Shannon-Wiener diversity values are shown in Table 3 for all samples collected during the study.

Table 2: Inventory of all benthic macrofaunal species collected in grab and diver-collected samples from Black Ledge area.

POLYCHAETA

Aglaophamus neotenus
Ampharete arctica
Ampharetidae unid.
Amphecteis gunneri
Amphitrite johnstoni
Amphitrite sp.
Anaitides mucosa
Anaitides sp.
Aricidea sp.
Asabellides oculata
Autolytus sp.
Capitella capitata
Cirratulus sp.
Clymenella torquata
Cossura longocirrata
Disoma carica
Dorvilleidae unid.
Drilonereis longa
Drilonereis magna
Ephesiella minuta
Euchone sp.
Eulalia viridis
Eumida sanguinea
Eunicea unid.
Exogone sp.
Glycera americana
Harmothoe imbricata
Lepidonotus squamatus
Lepidonotus sublevis
Lumbrineris sp.
Maldanopsis elongata
Marphysa sanguinea
Mediomastus ambiseta
Melinna cristata
Nephtys incisa
Nephtys picta
Nereis arenaceodonta
Nereis pelagica
Nereis succinea
Nereis virens
Nicolea venustula
Ninoe nigripes
Notomastus sp.
Oligochaeta
Onuphis quadricuspis
Orbiniidae unid.
Paraonis fulgens
Paraonis sp.
Parapionosyllis longicirrata
Pectinaria gouldii
Pherusa affinis
Pholoe minuta
Phyllodocidae unid.
Pista palmata
Polycirrus eximius
Polydora socialis
Polydora sp.
Polygordius sp.
Potamilla neglecta
Potamilla reniformis
Prionospio cirrifera
Pygospio elegans
Sabellaria vulgaris
Scalibregma inflatum
Scolelepis squamata
Scoloplos acutus
Sigambra tentaculata
Sphaerosyllis sp.
Spiochaetopterus oculatus
Spionidae unid.
Spiophanes bombyx
Sthenelais boa
Sthenelais limicola
Streblospio benedicti
Syllinae/Eusyllinae unid.
Tharyx acutus

GASTROPODA

Acteocina canaliculata
Alvania sp.
Anachis avara
Buccinum sp.
Busycon canaliculatum
Cingula aculeus
Colus obesa
Crassinella lunulata
Crepidula fornicata
Crepidula plana
Cylichna oryza
Epitonium humphreysi
Lacuna vincta
Lunatia heros
Lunatia triseriata
Mitrella dissimilis
Mitrella lunata
Nassarius trivittatus
Odostomia gibbosa
Odostomia seminuda
Philine lima
Skeneopis planorbis
Turbonilla sp.
Urosalpinx cinerea

Table 2 (cont.)

BIVALVIA

Astarte undata
Bivalvia unid.
Cerastoderma pinnulatum
Crenella glandula
Cumingia tellinoides
Cyclocardium borealis
Ensis directus
Lyonsia hyalina
Macoma balthica
Mercenaria mercenaria
Modiolus modiolus
Mulinia lateralis
Mytilus edulis
Nucula delphinodonta
Nucula proxima
Petricola pholadiformis
Pitar morrhuanus
Solemya velum
Tellina agilis
Thracia conradi
Yoldia limatula

AMPHIPODA

Ampelisca abdita
Ampelisca vadorum
Ampelisca verrilli
Amphithoe longimana
Byblis serrata
Caprellidae unid.
Corophium acutum
Corophium bonelli
Dexamine thea
Elasmopus levis
Erichthonius rubricornis
Jassa falcata
Lembos websteri
Leptocheirus pinguis
Lysianopsis alba
Microdeutopus gryllotalpa
Paraphoxus spinosus
Photis sp.
Phoxocephalus holbolli
Pleusymtes glaber
Stenothoe minuta
Trichophoxus epitomus
Unciola irrorata

CRUSTACEA

Campylaspis rubicunda
Cancer borealis
Cancer irroratus
Crangon septemspinosa
Cylindroleberis mariae
Cythereis vineyardensis
Edotea triloba
Erichsonella filiformis
Eudorella pusilla
Heteromysis formosa
Idotea phosphorea
Iphinoe trispinosa
Leptochelia savignyi
Libinia dubia
Libinia sp.
Mysidacea unid.
Neopanope sayi
Ostracoda unid.
Oxyurostylis smithi
Pagurus longicarpus
Pinnotheres maculatus
Ptilanthura tenuis
Pycnogonida unid.
Sarsiella sp.
Upogebia affinis

MISCELLANEOUS

Amphipholis squamata
Arbacia sp.
Asterias forbesi
Cerebratulus sp.
Cerianthus sp.
Edwardsia sp.
Enteropneusta unid.
Henricia sanguinolenta
Metridium senile
Nemertea unid.
Phoronida unid.
Sipuncula unid.
Tubulanus pellucidus

Table 3: Faunal sample parameter summary: S = number of species/taxa; N = number of individuals/m^2; H' = Shannon-Wiener diversity; J' = evenness.

Station	S	N	H'	J'
1-1	35	30,575	2.1604	.4212
1-2	20	43,825	1.4644	.3388
2-1	24	18,375	2.0321	.4432
2-2	26	26,875	1.9969	.4248
3-1	45	32,950	2.1326	.3883
3-2	37	29,000	1.6079	.3087
4-1	38	30,800	1.5787	.3008
4-2	45	29,075	1.4146	.3716
5-1	41	65,250	0.6973	.1301
5-2	40	60,000	1.1754	.2194
A5-1	46	6,924	2.2326	.5831
A5-2	25	5,978	1.5781	.4903
B5-1	24	10,404	1.2934	.4070
B5-2	24	5,574	1.6983	.5344
B10-1	41	14,160	2.7567	.5145
B10-2	23	6,795	1.5586	.3446
B20-1	47	6,033	4.0859	.7356
B20-2	60	7,824	4.4363	.7510
B30-1	59	5,069	4.1092	.6985
B30-2	47	7,521	3.9836	.7172
C5-1	23	18,935	1.4649	.3238
C5-2	35	9,036	2.7458	.5353
C10-1	23	16,630	2.3797	.5261
C10-2	30	4,637	2.9465	.6005
C20-1	38	4,968	4.2017	.8006
C20-2	35	6,924	4.0017	.7802
C30-1	34	9,925	3.9905	.7844
C30-2	35	10,225	3.7368	.7285

Species richness values are raw numbers of species (and/or taxa) for each sample; the faunal density values have been extrapolated to numbers per square meter due to the difference in sample size between the grab ($0.04m^2$) and the diver-quadrat ($0.11m^2$) samples. Because of this difference, the species richness and diversity values are not strictly comparable between the two sampling methods. There is no way to correct for sample size for these parameters with so few replicates per station.

Species richness, plotted in Figure 5, varied from 20 to 60 taxa per station ($\bar{x} = 35.7$). The shallow rocky substratum stations typically supported fewer taxa ($\bar{x} = 29.4$) than either the sand/gravel stations ($\bar{x} = 44.4$) or the silt/clay stations ($\bar{x} = 35.1$). Because of the difference in sample size, it is not possible to determine whether the silt/clay or sand/gravel group supported more taxonomic variety per unit area. The difference between the rock and sand/gravel stations can be tested statistically because both were sampled with the air-lift method. Species richness at the sand/gravel stations was found to be significantly greater at $p < .01$.

The pattern of faunal density, shown in Figure 6, did not follow that described above for species richness. The silt/clay substratum stations had greatest densities ($\bar{x} = 36{,}672/m^2$), followed by the rock stations ($\bar{x} = 9{,}907/m^2$) and the sand/gravel stations ($\bar{x} = 7{,}311/m^2$). These values do not exhibit the extreme variation between stations typical of areas which are receiving anthropogenic impacts in the form of organic overenrichment. In Bridgeport and Black Rock Harbors (CEM, 1981), stations receiving the most acute impacts were azoic or supported very few species and individuals. At Black Ledge, no areas with faunal characteristics approaching this type of situation were found. Greatest faunal densities at Bridgeport and Black Rock were found at stations adjacent to the zone of most acute impacts in sand/gravel sediments. Faunal populations in these areas comprised predominantly Stage I polychaete species. At Black Ledge, greatest densities were in silt/clay strata which were not in proximity to any azoic areas. The elevated densities in these areas were due to extremely dense populations of the the amphipod *Ampelisca abdita*, a Stage II species, and the polychaete *Aricidea* sp., which is not considered to be a Stage I species.

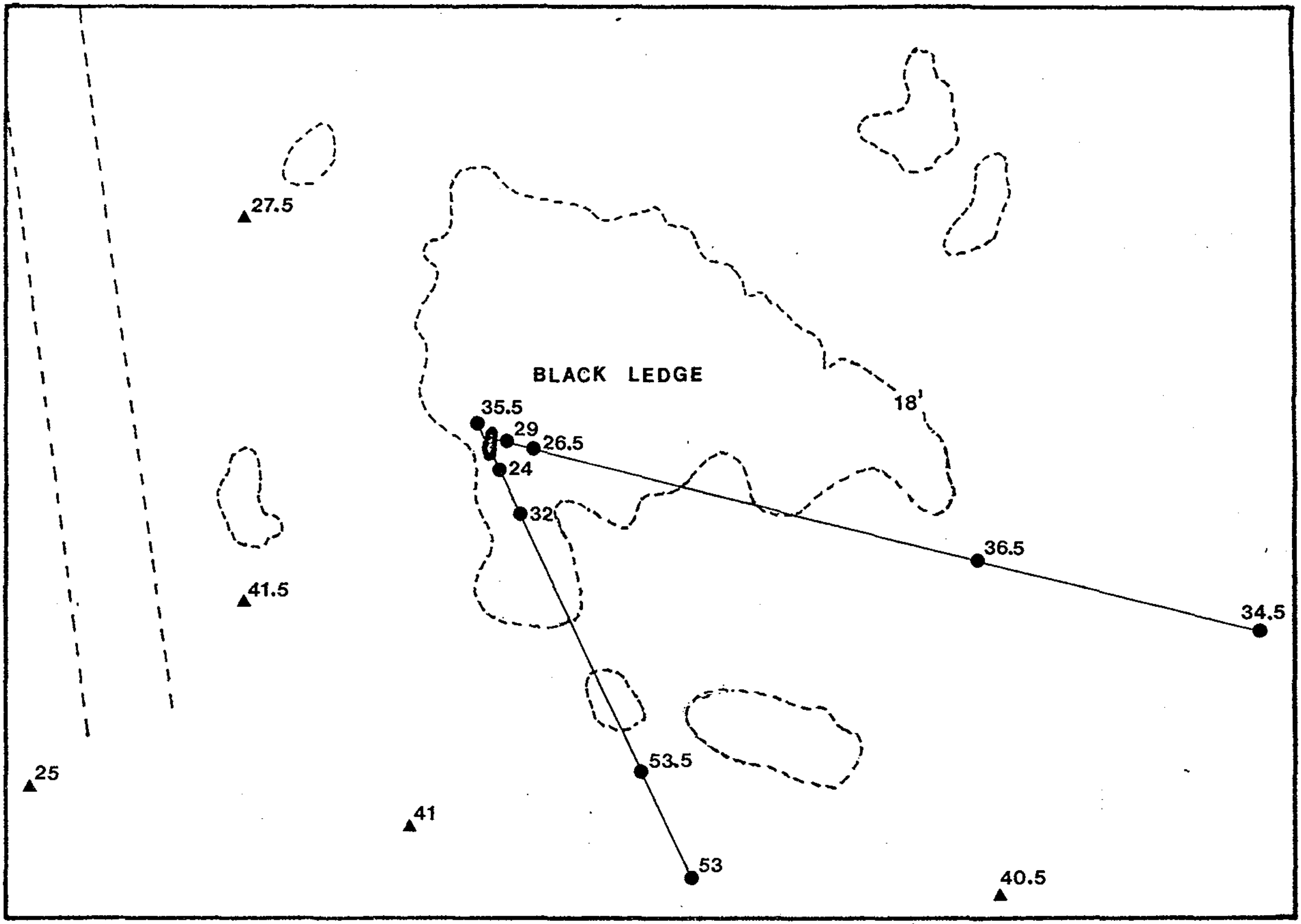

Figure 5: Plot of species richness values for stations sampled at Black Ledge. Counts are number of species or taxa per $0.04m^2$ for grab samples, per $0.1m^2$ for diver collected samples.

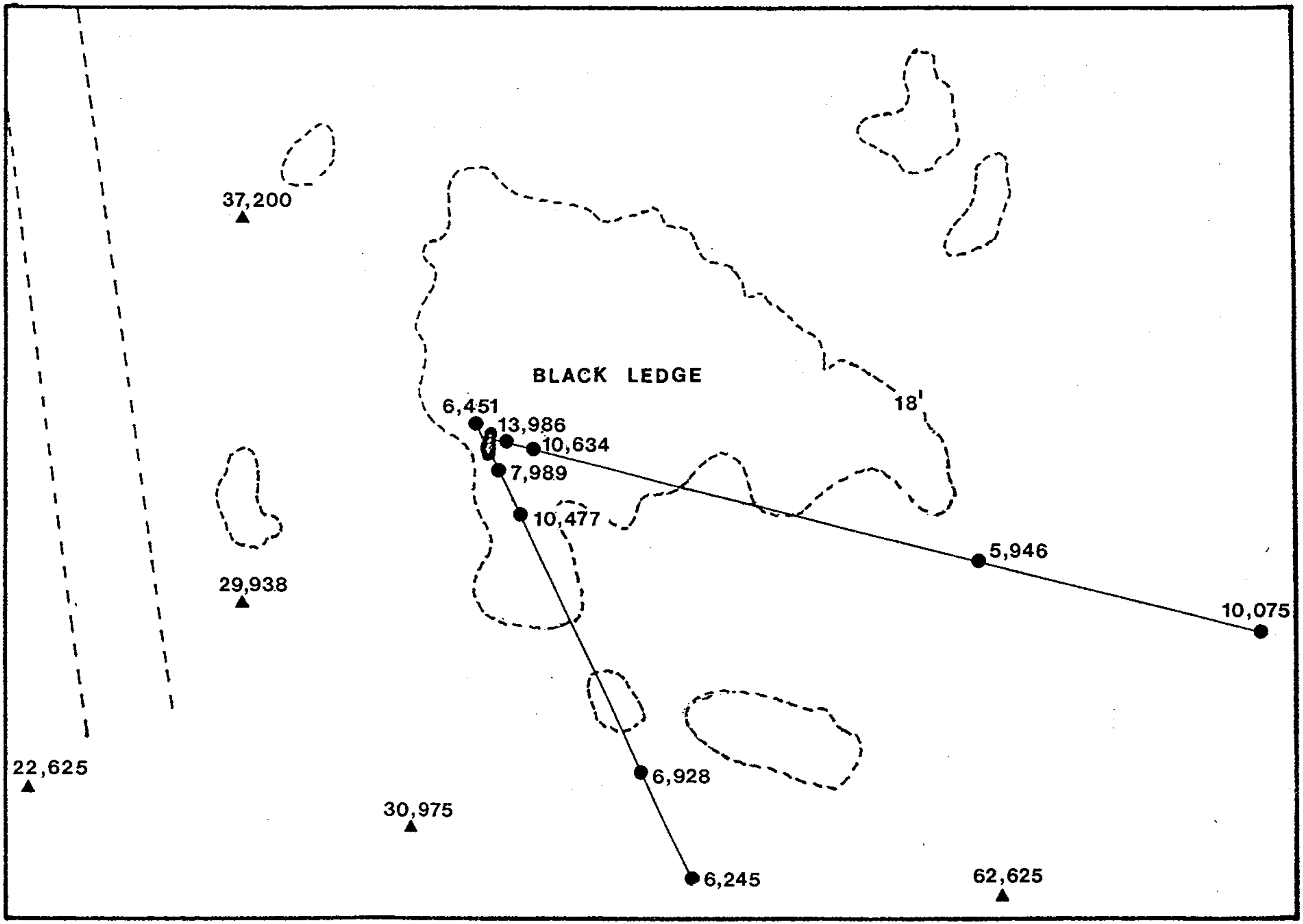

Figure 6: Plot of faunal density values for stations sampled at Black Ledge. All counts normalized to individuals/m^2.

Shannon-Wiener species diversity (H') and evenness (J') are shown in Table 3. As is typically the case with these indices, diversity was not strongly related to the species richness of the communities sampled ($r = .1044$) but was very dependent ($r = .5856$) on J', which is considered to be a measure of how evenly resources are partitioned between the various species. The relationship of evenness to diversity must be considered when interpreting a set of diversity values, particularly when large differences in evenness are apparent between stations, as is the case for the Black Ledge data.

Because of this relationship between diversity and evenness, the deeper silt/clay substrata stations, where dense populations of *Aricidea* sp. or *Ampelisca abdita* occurred, generally had low diversity values (<2.2) in spite of their moderately high species richness and extremely high faunal density. Evenness values in these areas were typically less than 0.45, indicating that most of the contribution to the overall faunal density was by a few dominant species.

Diversities at the shallow rock substratum stations were higher than at the silt/clay stations despite the depressed species richness and markedly lower faunal density found in the former area. Evenness values were sufficiently higher here to explain this result. In addition, all faunal community parameters were more variable in this area, reflecting the greater spatial heterogeneity inherent in a shallow hard-bottom habitat.

The intermediate depth sand/gravel stations on the transects to the south and east of Black Ledge, although they had the least dense faunal populations, had the highest diversities. This was primarily due to the elevated evenness values in this area ($>.70$) in combination with the high species richness noted earlier.

The observed patterns of species richness, faunal density and species diversity, when all three parameters are considered, appear clearly related to bottom stability. The shallow hard rock substrata are occupied by a community of low species richness and standing stocks which displays marked spatial and, presumably, temporal variation. The intermediate depth sand/gravel substrata in the area support a transitional community which has low standing stocks but elevated species

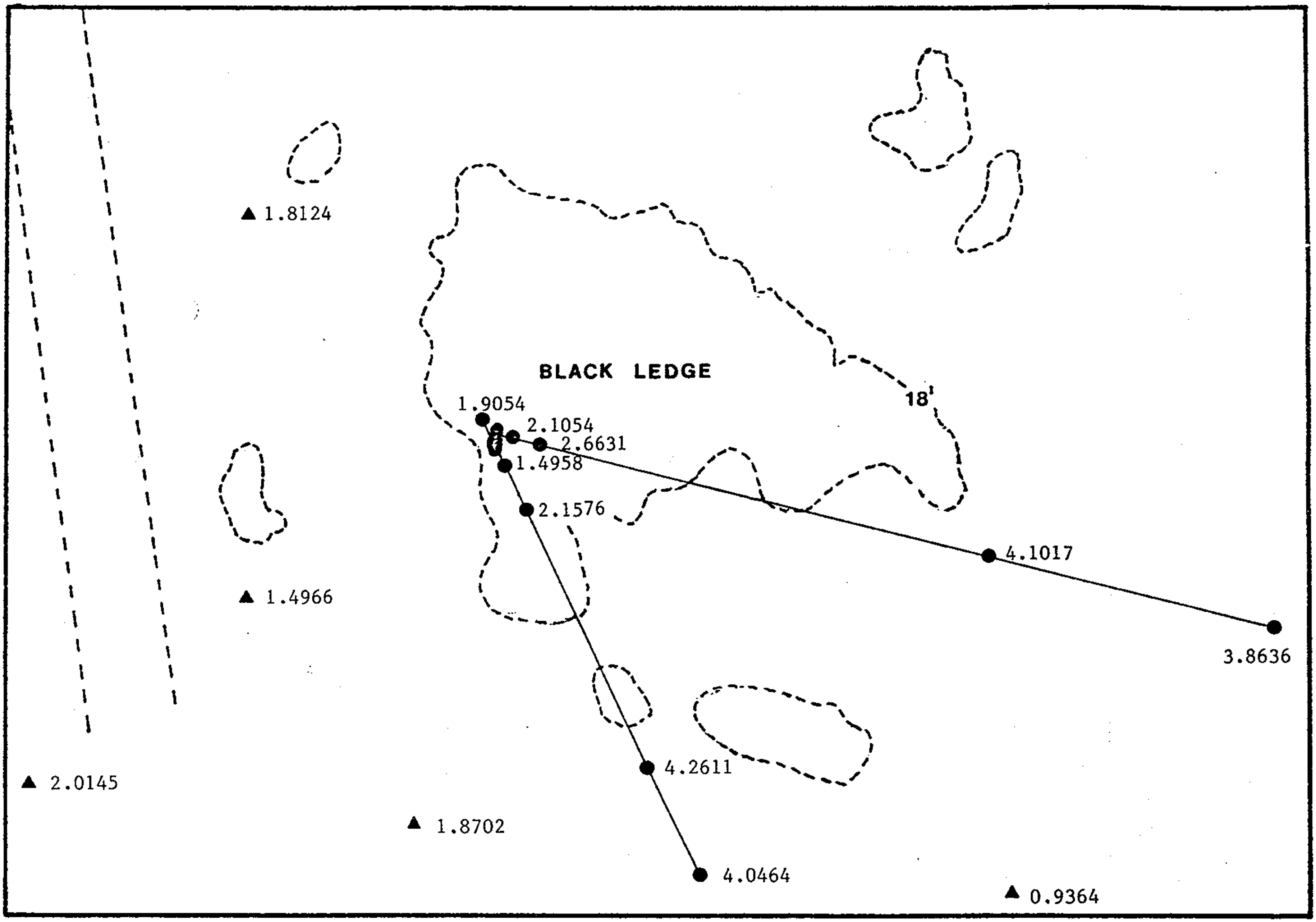

Figure 7: Shannon-Wiener diversity (H') values for stations sampled at Black Ledge. Values displayed are means for two replicates.

richness and diversity. The relatively greater spatial and temporal homogeneity at the deeper silt/clay stations results in a community with elevated species richness and standing stock, but depressed diversity due to strong dominance by one or two species. The community characteristics of this last group of stations will be discussed in greater detail in Section 3.2.4. of this report.

3.2.3. Community Classification Analysis

A classification, or cluster, analysis was performed using data on dominant species. A dominant species was defined as one which occurred among the top five numerical dominants in at least two replicates; 26 species (or taxa) qualified under that criterion.

An inverse (R-mode) analysis was conducted using program BMDP1M of the Biomedical Computer Programs package, on the VAX 11/780 system at WHOI. The similarity index used in the analysis was product-moment correlation and linkage was accomplished using unweighted pair-group arithmetic averages (UPGMA). Results are shown as a dendrogram in Figure 9. Program BMDP2M was used to perform a normal (Q-mode) analysis on the same data. The similarity index used for the normal analysis was the chi-square test of equality and the linkage procedure was UPGMA. Results are shown as a dendrogram in Figure 8.

Inspection of the inverse dendrogram indicates six recognizable clusters among the 26 species, as indicated by the dashed lines. The first group (A) includes the polychaetes *Aricidea* sp., *Mediomastus ambiseta* and *Nephtys incisa*, and the bivalve *Nucula proxima*. A second, somewhat related group (B) includes two amphipod species, *Ampelisca abdita* and *Corophium bonelli*, and *Anaitides maculata*, a polychaete. The largest group (C) occupies the center of the dendrogram and includes the polychaetes *Exogone* sp., *Polycirrus* sp., and *Capitella capitata*, the oligochaetes, *Polygordius* sp., an archiannelid, and the tanaid *Leptochelia savignyi*. The (C) group is followed by the related group (D) which comprises the amphipods *Unciola irrorata* and *Ampelisca vadorum* and the polychaete *Spiophanes bombyx*. All four of the preceding groups were more closely related to each other than to the two following groups.

Group (E) included the gastropod *Mitrella lunata*, the bivalve

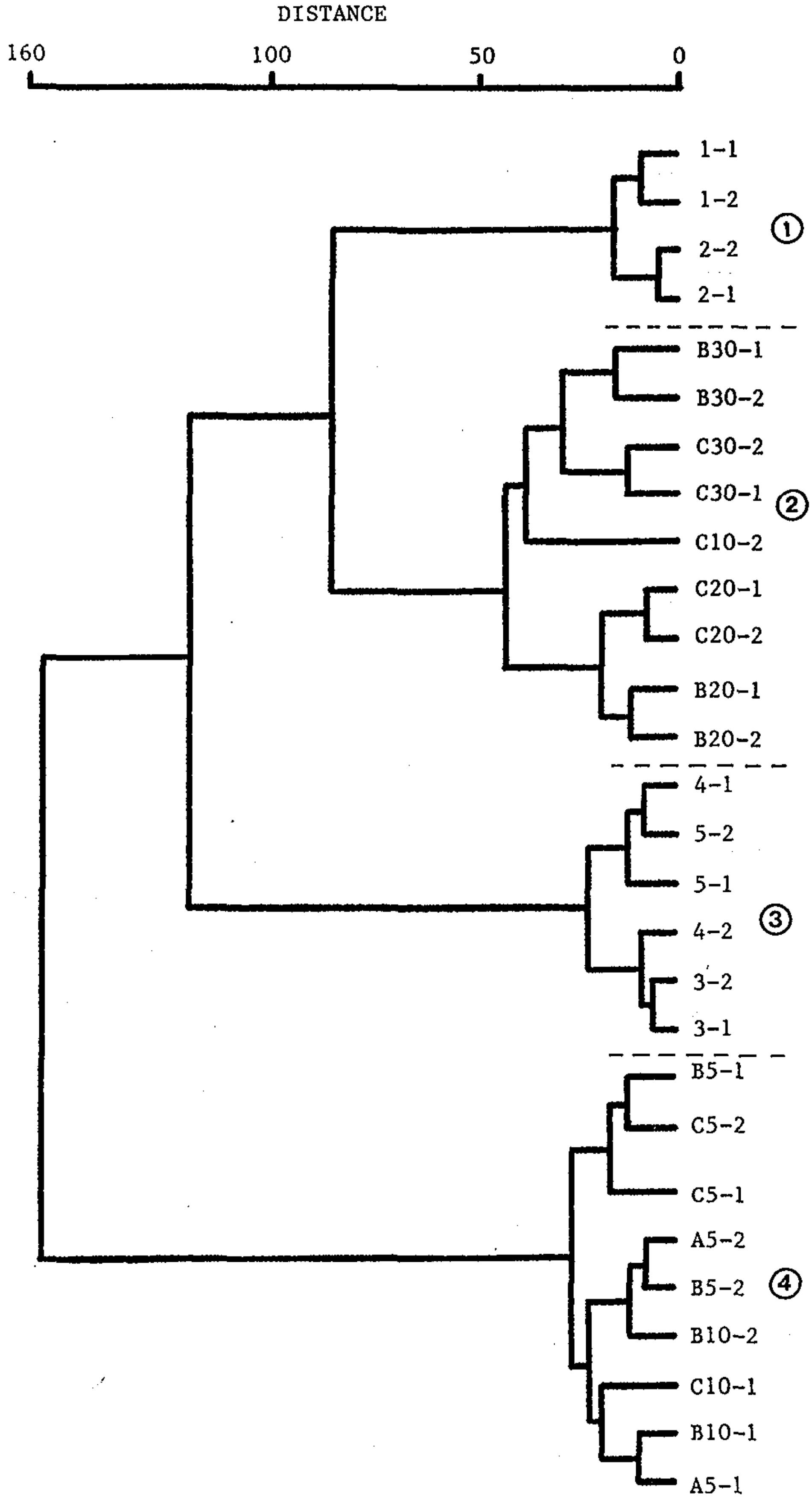

Figure 8: Normal (Q-mode) dendrogram showing relationships among stations/replicates for Black Ledge sampling.

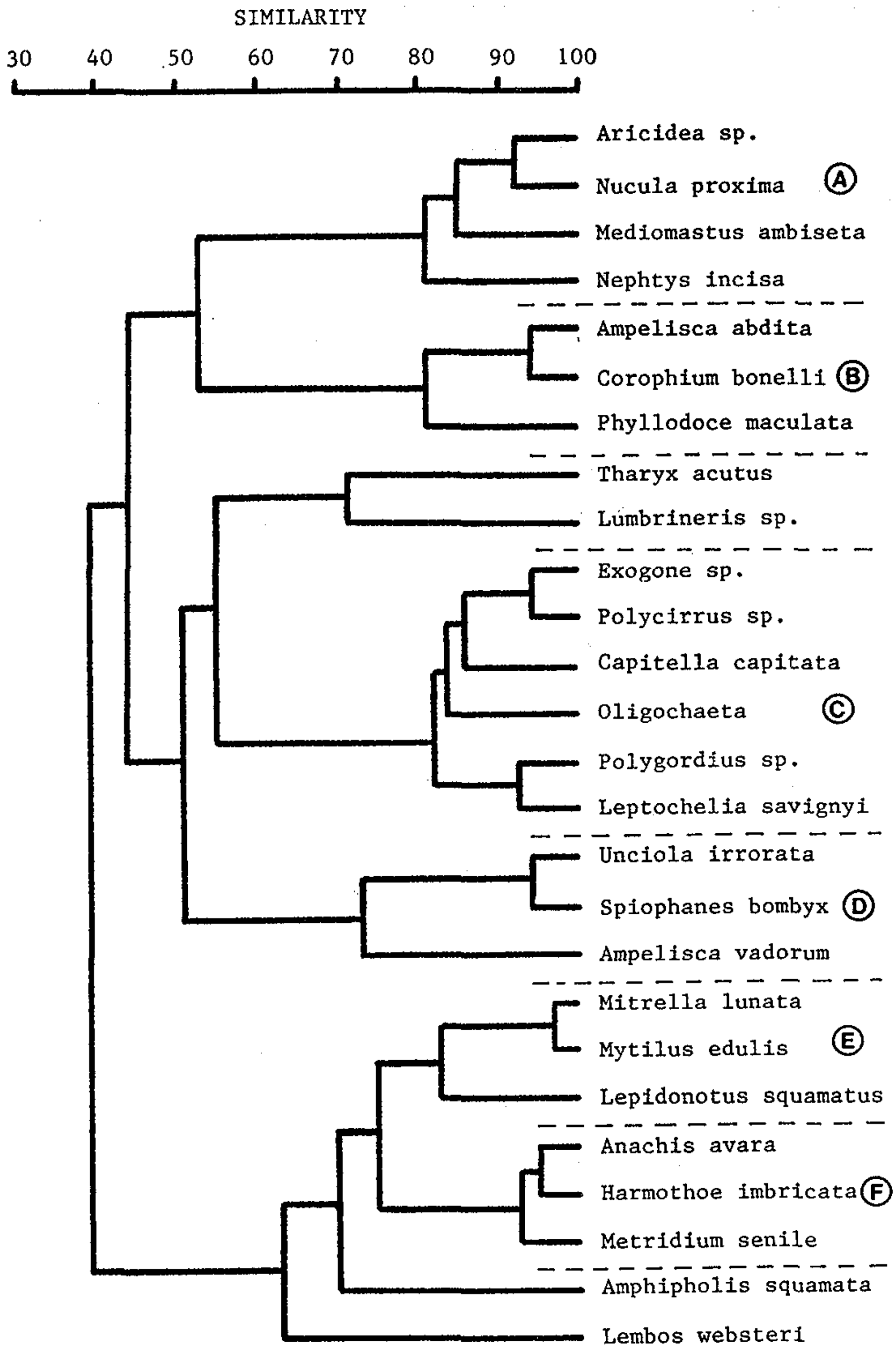

Figure 9: Inverse (R-mode) dendrogram showing relationships among 26 most common species from Black Ledge sampling.

Mytilus edulis, and the polychaete Lepidonotus squamatus. The related group (F) comprised the gastropod Anachis avara, the polychaete Harmothoe imbricata and the anthozoan Metridium senile.

Inspection of the normal dendrogram (Figure 8) revealed four distinct and homogeneous clusterings. The first of these (Group 1) included Stations 1 and 2, which were of moderate depth (25' - 30') and had a silty substratum. Group 2 included stations to the south and east of Black Ledge which were of moderate to shallow depth (10' - 30') and had a sand/gravel substratum. Group 3 included the three deepest (>30') stations sampled, all of which had silty bottoms, and Group 4 comprised the five rock substratum stations on Black Ledge proper. These clusters correspond nearly exactly to the groupings discussed earlier which were identified on the basis of substratum characteristics.

The relationships among the six species groups and four station groups identified above were examined via nodal analysis (Boesch, 1977). Scores at each station/species node were calculated as the percent of the maximum possible number of occurrences of the species as dominants (top five, numerically) at the stations. For example, the intersection of a three-member species group with a five-member station group would have a maximum of 15 possible "occurrences" if each of the species were present as a dominant at each of the stations. If the species were present as dominants a total of 12 times, the score at that node would be 80.0% (12/15 X 100). The calculated nodal density scores, arranged into four density levels, are presented in Figure 10.

Species Group A, dominated by Aricidea sp., was restricted to the deep silt substratum stations, being most commonly found at station Group 1, but also occurring at Group 3. Species Group B, dominated by Ampelisca abdita, was characteristic of the deepest stations (Group 3) and occurred nowhere else. Based upon this pattern, these stations are clearly unique in relation to the remainder of the area surveyed.

Station Group 2, the moderately deep sand/gravel stations, was dominated by species Group C but also contained moderate densities of Group D, containing species which appeared to be transitional between the shallower hard substrata and the deeper silt/clays. Species Group E and Group F were characteristic of the rock stations, with Group F being more strongly restricted to this habitat than Group E.

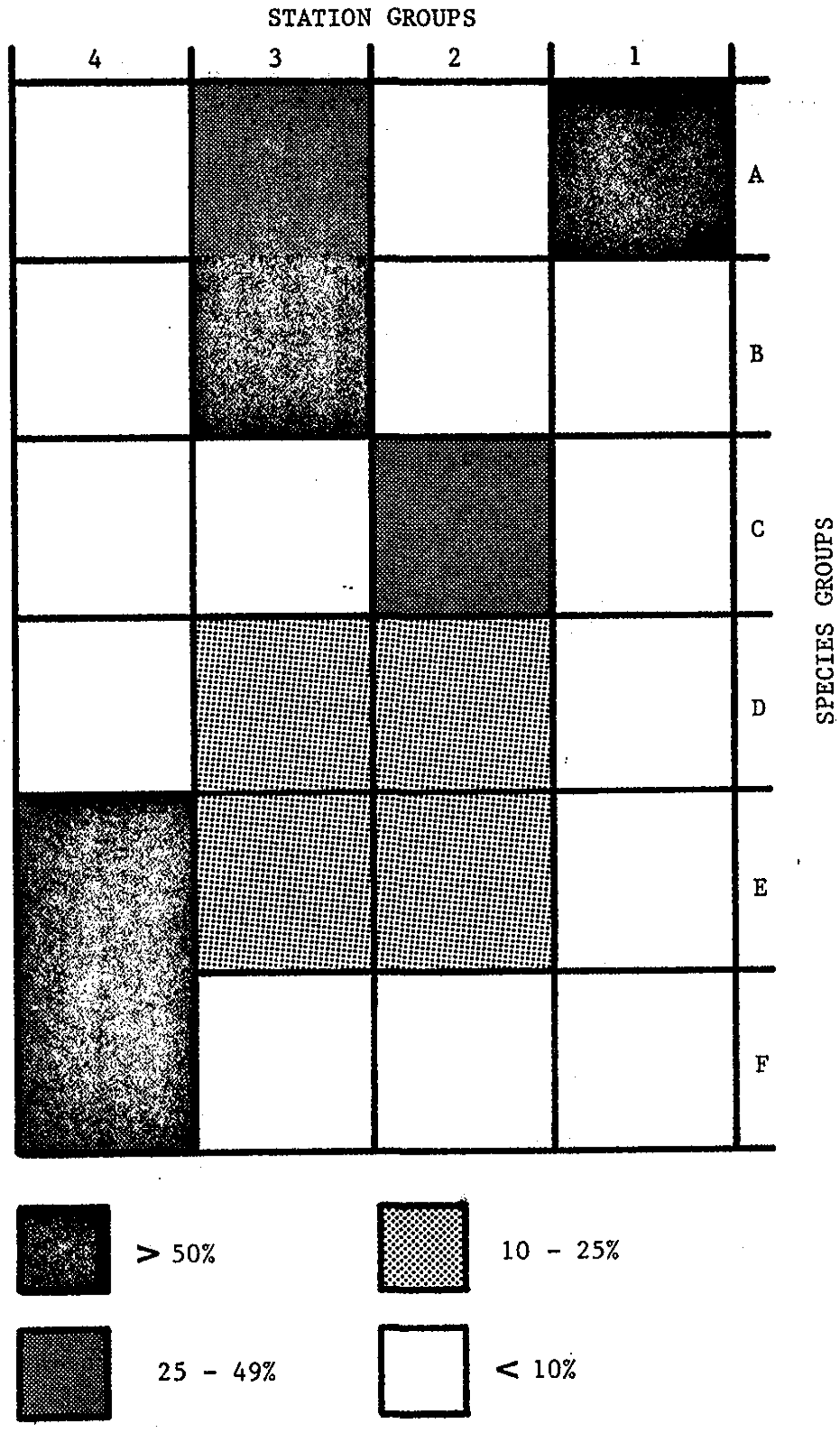

Figure 10: Nodal analysis showing occurrence of species groups (A-F) at station groups (1-4) at Black Ledge. For explanation of nodal density scores, see text.

3.2.4. Habitat Valuation

Three distinct community types were identified from the classification anlysis; one of these (silt/clay)was further divided into two sub-classes. Four of the five stations grouped into the silt/clay group were sampled via REMOTS methodology in addition to the conventional macrofaunal sampling, and therefore more data are available for the habitat analysis phase of the program. The results of the analysis of the REMOTS imagery are shown in Table 4.

Stations 1 and 2 were unlike any other stations and comprised a silt/clay substratum dominated by a suite of polychaete species, primarily the paraonid, *Aricidea* sp. Also common were the polychaetes *Scoloplos acutus* and *Tharyx acutus*. The most common non-polychaete species was the bivalve *Nucula proxima*. REMOTS imagery indicated that these stations had an average oxidized area of approximately 25cm^2 with no sediment methane. Although the dominant polychaete in this assemblage (*Aricidea*) is not one of the more typical Stage I species, the remainder of the community is indicative of Stage I (polychaete-dominated) succession.

Based upon the habitat evaluation procedure described earlier, this area was awarded a habitat index of 4 - 5, with Station 2 scoring slightly higher than Station 1. These are relatively high indices for this community type and suggests that the area has not been subjected to a great amount of pollution-related stress. More typical Stage I assemblages in heavily polluted regions of harbors have habitat values of 1 to 3.

The remainder of the silt/clay substratum stations (3,4,5) supported faunal communities dominated by the ampeliscid amphipod, *Ampelisca abdita*. Prominent sub-dominant species included *Nephtys incisa*, *Nucula proxima*, *N. delphinodonta* and *Mitrella lunata*. Although there was no discernable difference in sediment type between the two silt/clay community types, the amphipod-dominated community definitely presents a picture of greater stability.

REMOTS imagery from Stations 3 and 4 (Table 4) also indicated a lack of methanogenesis and a considerably larger oxidized layer

Table 4: Scores by station and replicate for parameters used in evaluating imagery obtained by REMOTS photography.

Station	Sediment Type	P	Redox(cm^2)	CH_4	Successional Stage	Habitat Index
1-1	4 - 3Ø	4.6	19.2	no	I	3
1-2	4 - 3Ø	5.1	27.5	no	I	4
1-3	4 - 3Ø	4.6	26.6	no	I	4
1-4	4 - 3Ø	4.6	28.9	no	I	4
1-5	4 - 3Ø	4.8	23.2	no	I	4
2-1	4 - 3Ø	3.9	30.8	no	I	5
2-2	4 - 3Ø	4.3	19.6	no	I	3
2-3	4 - 3Ø	3.5	34.1	no	I	5
2-4	4 - 3Ø	4.2	33.1	no	I	5
2-5	4 - 3Ø	3.9	21.5	no	I	4
2-6	4 - 3Ø	4.8	28.2	no	I	4
3-1	4 - 3Ø	4.0	37.0	no	II	7
3-2	4 - 3Ø	3.9	41.3	no	II	8
3-3	4 - 3Ø	3.9	40.2	no	II	8
3-4	4 - 3Ø	3.9	39.1	no	II	7
3-5	4 - 3Ø	4.0	37.3	no	II	7
4-1	4 - 2Ø	4.1	44.0	no	II	7
4-2	4 - 2Ø	5.2	31.8	no	II	7
4-3	4 - 2Ø	3.0	36.3	no	II	6
4-4	4 - 2Ø	4.2	41.0	no	II	7
4-5	4 - 2Ø	4.8	60.3	no	II	8

than Stations 1 and 2 ($\bar{x} = 42.5cm^2$). Primarily because of the Stage II amphipod-dominated community at Stations 3 and 4, this area received a higher habitat index of 7 - 8, with no difference between the two stations. Although Station 5 was not sampled with the REMOTS methodology, it is clear from the similarity in the faunal and sediment composition that this station would also receive a similarly high index. The distribution of mean habitat indices over the four stations sampled via REMOTS methodology is shown in Figure 11.

The four sand/gravel substratum stations (B20, B30, C20, C30) represent a heterogeneous group of faunal assemblages which have characteristics of both Stage I and Stage II communities. Polychaete species dominate most of the samples from these stations, particularly at B20 and B30, but crustaceans are also common and Ampelisca abdita is one of the dominants at Station C30.

It was not possible to obtain REMOTS imagery at these stations due to the nature of the substratum and the program scope. Therefore, it is not possible to assign a habitat index value which can be compared directly with those assigned to the silt/clay stations. Based upon the faunal assemblages at these locations, however, it appears that the sand/gravel stations would have indices intermediate between the Stage I and Stage II silt/clay stations. Stations on the B transect, which were more strongly polychaete-dominated, would score toward the lower end of this range while stations on the C transect, with their larger crustacean components, would be ranked toward the upper end of the range.

The remaining five stations (A5, B5, B10, C5, C10) are all located on the shallower area of Black Ledge and share a rock substratum. These stations are occupied by a faunal assemblage which is entirely different from that described at the deeper stations. The dominant species in all cases was the edible mussel, Mytilus edulis, and sub-dominants included the gastropods Mitrella lunata and Anachis avara, the polychaete Harmothoe imbricata and the ophiuroid Amphipholis squamata. These are all typical hard-substratum species with a wide distribution in the northeast littoral.

REMOTS technology is not applicable to hard bottoms and therefore was not used at any of the rock substratum stations.

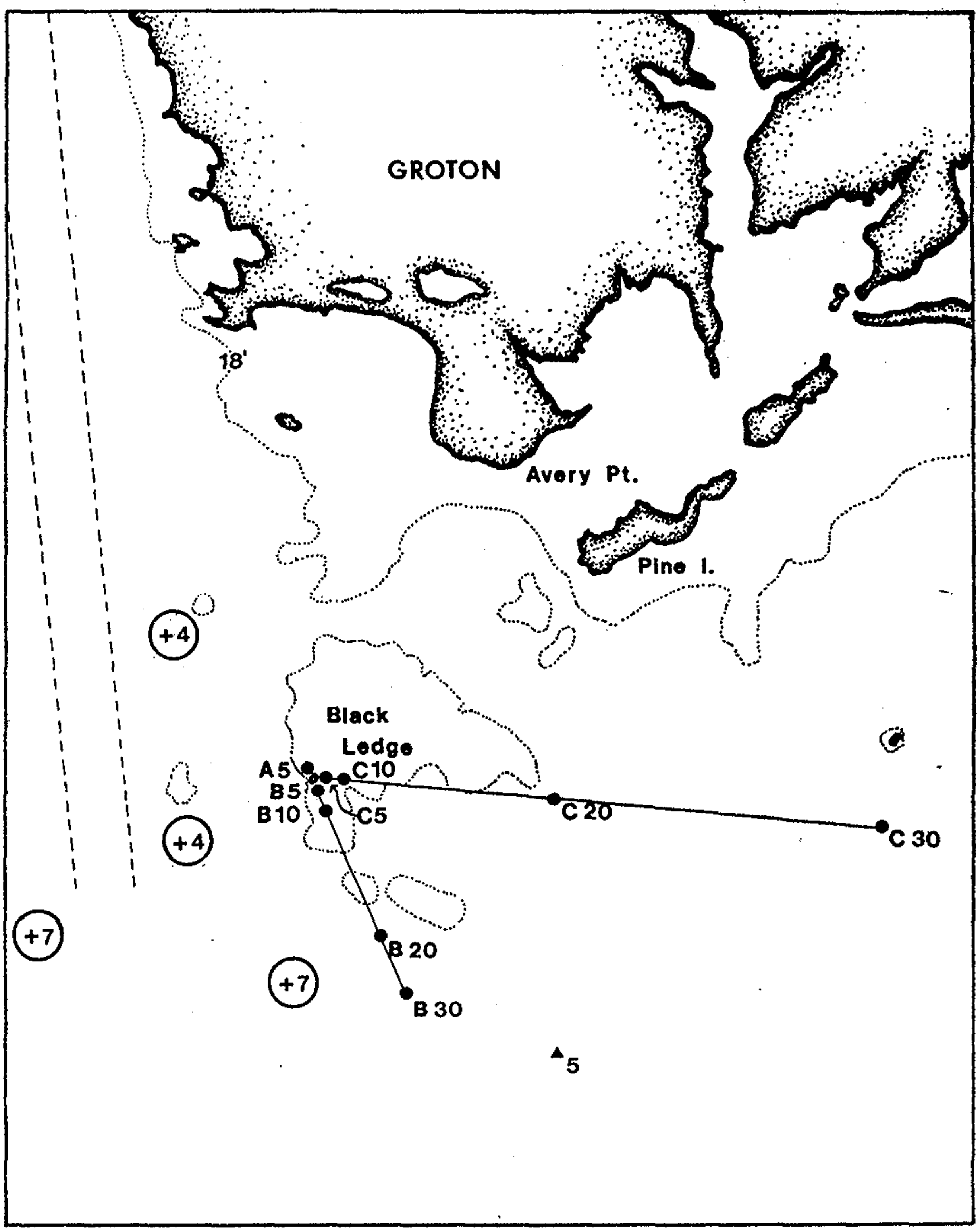

Figure 11: Plot of habitat index scores for four stations at Black Ledge evaluated by REMOTS imagery. Scale ranges from -10 to +10.

Because much of the habitat index is based upon sedimentary parameters (redox layer, methanogenesis), it is not possible to develop habitat index values for the rock substratum stations which would be comparable to those described for the silt/clay and sand/gravel substrata.

Based upon our experience with rock substratum communities in other areas, however, the faunal assemblage at Black Ledge appears normal and unimpacted by pollution-related stress. Mytilus is a common dominant species in similar communities in similar situations and is capable of reaching extremely high levels of productivity. Because of that, it is likely that the rock substratum communities at Black Ledge represent a very valuable ecological resource in spite of their reduced species richness and faunal density.

3.3. Black Ledge Algae

3.3.1. Species Richness

Algal colonization at Black Ledge was restricted to the rock substratum stations, i.e. the 5' and 10' stations of the A, B, and C transects. The rocks sampled were all large and artificially-cut; naturally occurring rocks associated with the ledge structure itself were not present in the sampling area.

A total of 52 algal species was recorded from the Black Ledge subtidal stations (Table 5). Species richness did not appear to be correlated with either depth or transect; richness was relativey high throughout the survey area for all replicates and stations. The number of species contained in individual replicates (Table 6) showed moderate variation, and ranged from a minimum of 22 to a maximum of 33; the average number of species contained in each replicate was 27. The number of species recorded for each station showed considerably less variation, ranging from a low of 36 to a high of 38.

The number of species representing each major algal division was also similar for all stations, regardless of depth or transect. Red algal species (Rhodophyta) predominated throughout the survey area, and comprised between 64 and 70% of the total species number at the individual stations. Green algal species (Chlorophyta) and brown algal species

Table 5. Algal species collected at the subtidal (5' and 10' MLW) rock substratum Black Ledge stations, by depth, transect, and replicate.

Division Species	5' (A) Rep 1	 Rep 2	5' (B) Rep 1	 Rep 2	5' (C) Rep 1	 Rep 2	10' (B) Rep 1	 Rep 2	10' (C) Rep 1	 Rep 2
	Depth (Transect)									
Green algae (Chlorophyta)										
Enteromorpha clathrata	X	X								
Enteromorpha flexuosa		X				X		X		
Enteromorpha intestinalis			X				X			
Enteromorpha prolifera				X	X					X
Ulva lactuca	X	X	X	X	X	X	X	X	X	X
Chaetomorpha linum		X	X			X	X	X		
Chaetomorpha melagonium			X							
Cladophora albida					X			X		X
Cladophora sericea		X	X	X		X				
Rhizoclonium riparium				X						
Bryopsis plumosa		X					X		X	
Brown algae (Phaeophyta)										
Ectocarpus fasciculatus				X		X	X			
Ectocarpus siliculosus	X	X	X	X	X	X	X	X	X	X
Giffordia granulosa	X	X	X	X	X	X	X	X	X	X
Giffordia mitchelliae		X		X			X		X	X
Giffordia sandriana		X		X		X			X	
Desmarestia aculeata			X						X	
Laminaria saccharina	X							X		X
Sphacelaria cirrosa		X				X			X	X
Red algae (Rhodophyta)										
Goniotrichum alsidii	X					X				X
Bangia atropurpurea		X		X	X		X		X	X
Porphyra leucosticta		X	X							

Table 5. (continued)

	Depth (Transect)									
	5' (A)		5' (B)		5' (C)		10' (B)		10' (C)	
	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
Porphyra umbilicalis					X			X		X
Audouinella daviesii	X	X	X	X	X	X	X	X	X	X
Audouinella secundata	X						X	X		X
Nemalion helminthoides		X								
Bonnemaisonia hamifera							X		X	
Polyides rotundus		X	X		X		X	X		
Cystoclonium purpureum		X		X		X		X	X	X
Ahnfeltia plicata				X	X		X	X		X
Phyllophora pseudoceranoides		X	X		X	X		X		X
Phyllophora truncata	X				X	X	X		X	
Chondrus crispus	X	X				X		X	X	X
Corallina officinalis			X	X	X		X		X	
Champia parvula		X	X			X			X	X
Lomentaria baileyana		X				X		X		
Lomentaria orchadensis	X	X	X	X	X	X	X	X	X	X
Antithamnion americanum			X				X			
Antithamnion cruciatum	X	X	X	X	X	X	X	X	X	X
Callithamnion baileyi	X	X	X	X	X	X		X	X	X
Callithamnion byssiodes	X	X	X		X					X
Callithamnion corymbosum			X				X		X	
Callithamnion roseum	X	X	X		X	X		X		
Ceramium rubrum	X	X	X	X	X	X	X	X	X	X
Spermothamnion repens	X	X	X	X	X	X	X	X	X	X
Grinnellia americana	X	X			X		X	X	X	X
Daysa baillouviana	X		X	X	X	X		X	X	X
Chondria tenuissima	X	X	X	X	X	X	X	X	X	X
Polysiphonia denudata	X	X	X	X	X	X	X	X	X	X
Polysiphonia harveyi	X	X	X	X	X	X	X	X	X	X
Polysiphonia nigrescens			X			X				X
Polysiphonia urceolata		X					X	X		

Table 6. Algal species richness and community structure at the subtidal (5' and 10') rock substratum Black Ledge stations a) by replicate and b) by station.

a) By replicate

Depth, transect, and replicate	Chlorophyta (green algae)	Phaeophyta (brown algae)	Rhodophyta (red algae)	Species richness
5,A,1	2 (9%)	3 (14%)	17 (77%)	22
5,A,2	6 (18%)	5 (15%)	22 (67%)	33
5,B,1	5 (18%)	3 (11%)	20 (71%)	28
5,B,2	4 (17%)	5 (22%)	14 (61%)	23
5,C,1	3 (12%)	2 (8%)	20 (80%)	25
5,C,2	4 (14%)	5 (18%)	19 (68%)	28
10,B,1	4 (15%)	4 (15%)	19 (70%)	27
10,B,2	4 (14%)	3 (11%)	21 (75%)	28
10,C,1	2 (8%)	6 (22%)	19 (70%)	27
10,C,2	3 (10%)	5 (17%)	22 (73%)	30

b) By station

Depth and transect	Chlorophyta (green algae)	Phaeophyta (brown algae)	Rhodophyta (red algae)	Species richness
5,A	6 (16%)	6 (16%)	26 (68%)	38
5,B	7 (19%)	6 (17%)	23 (64%)	36
5,C	6 (16%)	5 (14%)	26 (70%)	37
10,B	6 (16%)	5 (13%)	27 (71%)	38
10,C	4 (11%)	7 (19%)	26 (70%)	37

(Phaeophyta) were considerably less well represented; green algae comprised between 11 and 19% of the total species number at each station, while brown algal composition ranged between a very similar 13 to 19%. The prevalence of Rhodophycaen species is a characteristic feature of New England subtidal algal populations (Taylor, 1962).

3.3.2. Species Dominance

Species dominance patterns were also similar throughout the survey area and dominance appeared to be unrelated to both depth and transect. As a group, the dominant species at all replicates and stations consisted primarily of ephemeral and annual species of less than 5cm in height. More than 50% of the dominants were small (<4cm) filamentous epiphytic or epizoic species. Larger, perennial species (*Chondrus crispus*, *Phyllophora* spp., *Polyides rotundus*, *Corallina officinalis*, etc.) were poorly represented throughout the survey area, and were not among the dominant species for any replicate or station.

Table 7 presents the dominance heirarchies for each replicate and station. The red algae *Chondria tenuissima* was the dominant species throughout the survey area; *Chondria* was the single most dominant taxa in over 50% of the replicates, and was also the only taxa to be recorded as one of the five dominant species for every replicate. A second tier of dominant species comprised the brown alga *Giffordia granulosa* and the red algae *Lomentaria orchadensis* and *Callithamnion baileyi*. All three were among the five dominant species in 70 - 80% of the replicates. In addition, *Giffordia* was the most dominant species in three of the replicates, while *Callithamnion* was the dominant species in one replicate. A third tier of dominant species included the brown alga *Ectocarpus siliculosus*, the green alga *Ulva lactuca*, and the red algae *Polysiphonia denudata*, *P. harveyi*, and *Grinnellia americana*; all taxa were among the five dominant species in 20 - 30% of the replicates. A fourth tier of dominants comprised the red algae *Callithamnion roseum*, *Ceramium rubrum*, *Daysa baillouviana*, and *Cystoclonium purpureum*; all species were among the five dominant taxa in 10% of the replicates.

Dominance patterns were strongly influenced by the dense concentrations of *Mytilus* occurring at all stations. The benthic macroalgal

Table 7. Algal dominance at the subtidal (5' and 10') rock substratum Black Ledge stations, by depth, transect, and replicate.

Species	Depth (transect) 5' (A)		5' (B)		5' (C)		10' (B)		10' (C)	
	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
Chondria tenuissima	1	2	4	1	3	1	1	1	3	1
Giffordia granulosa	3	1	1	-	2	-	3	3	1	2
Lomentaria orchadensis	2	3	5	2	-	2	2	5	-	3
Callithamnion baileyi	4	-	-	5	1	3	-	2	2	4
Ectocarpus siliculosus	5	-	2	-	-	-	-	4	-	-
Polysiphonia denudata	-	4	-	3	-	-	-	-	-	5
Ulva lactuca	-	-	3	-	4	-	-	-	5	-
Polysiphonia harveyi	-	5	-	-	-	-	4	-	-	-
Grinnellia americana	-	-	-	4	-	-	-	-	4	-
Callithamnion roseum	-	-	-	-	-	4	-	-	-	-
Ceramium rubrum	-	-	-	-	-	5	-	-	-	-
Daysa baillouviana	-	-	-	-	-	-	5	-	-	-
Cystoclonium purpureum	-	-	-	-	5	-	-	-	-	-

species *Chondrus crispus* and *Phyllophora* spp., which typically dominate the New England subtidal flora (NUSCo, 1979; BECo, 1980), were not able to successfully compete against *Mytilus* for space. Dominance was instead shown by those epiphytic and ephemeral species which were able to germinate and grow directly upon *Mytilus*.

3.3.3. Community Overlap

Community overlap between stations was determined using Jaccard's Coefficient of Community (Grieg-Smith, 1964). Overlap did not appear to be related to either depth or transect (Table 8). Overlap values were generally high and uniform, ranging from 51.0 to 70.4%. The data indicate that algal species composition was relatively similar throughout the Black Ledge survey area.

3.3.4. Biomass

Biomass data for all replicates and stations are given in Table 9. Biomass varied considerably at both the replicate and station level; replicate biomass ranged from 4.3 to 152.1 g/m^2, and station biomass from 19.0 to 90.4 g/m^2. Biomass and depth appeared to be inversely related. 50% of the 5' replicates had biomass in excess of 100 g/m^2, while 100% of the 10' replicates had biomass below 50 g/m^2. In addition, the 5' stations consistently had greater biomass (67.9 - 90.4 g/m^2) than the 10' stations (19.0 - 42.5 g/m^2). Biomass and transect appeared to be unrelated.

Black Ledge biomass values were low compared to those recorded for corresponding shallow subtidal localities in New England. In studies conducted at Plymouth, Massachusetts (BECo, 1980), algal biomass typically ranged from 500 - 600 g/m^2, and values as high as 900 g/m^2 were not uncommon. The appreciably lower Black Ledge biomass was due to the scarcity of benthic macroscopic species; the small filamentous and blade-like species which dominated the Black Ledge populations contributed comparatively little to overall station biomass.

Table 8. Community overlap (Jaccard's Coefficient of Community) between the subtidal (5' and 10') rock substratum Black Ledge stations.

Station pair	number of shared species	community overlap
5A/5B	25	51.0%
5A/5C	31	70.4%
5A/10B	29	61.7%
5A/10C	28	59.6%
5B/5C	28	62.2%
5B/10B	26	54.2%
5B/10C	26	55.3%
5C/10B	29	63.0%
5C/10C	30	68.2%
10B/10C	29	63.0%

Table 9. Algal biomass (g/m^2) at the subtidal (5' and 10') rock substratum Black Ledge stations, by replicate and station.

Depth, transect, and replicate	replicate biomass (g/m^2)	station biomass (g/m^2)
5,A,1	44.6	90.4
5,A,2	136.2	
5,B,1	107.4	67.9
5,B,2	28.4	
5,C,1	152.1	89.0
5,C,2	26.9	
10,B,1	46.2	42.5
10,B,2	38.8	
10,C,1	33.7	19.0
10,C,2	4.3	

4.0. DISCUSSION AND CONCLUSIONS

The presence of mixed groups of Stage I and II faunal assemblages in the Black Ledge area is a typical pattern of successional mosaics in harbors. Periodic physical disturbance in these areas surrounding Black Ledge is apparently sufficient to prevent the establishment of communities with higher successional states. The frequency of disturbance appears to be greater for areas within the 30' isobath than for stations below this depth. However, even the deepest stations sampled exhibited evidence of a history of recurring periodic disturbance of sufficient magnitude to prevent establishment of a Stage III faunal assemblage. This pattern of disturbance may be related to winter storms, although Station 4 indicated more recent scouring in the REMOTS imagery.

On Black Ledge itself, wind and tidally driven currents and waves create a hydrodynamic regime which limits the fauna to those species adapted to a hard-bottom high-energy habitat. The depth to which this situation occurs at Black Ledge was not precisely determined by the present survey but would necessarily be between 10' and 20', and the ledge appeared to end abruptly at approximately 15' (MLW).

The most conspicuous feature of all stations on the ledge was a dense and virtually uninterrupted covering of mussels (*Mytilus edulis*) on all available rock surfaces. The mussel cover was at least one layer thick on most rocks, but occasionally swelled to two and even three layers in thickness. Mussel cover was commonly so complete that the underlying rock surfaces were not visible to divers. All mussels were similar in size (5 - 7cm) and were judged to be approximately one to two years of age.

The algal population on Black Ledge were characterized by an overall scarcity of benthic macroscopic species (*Chondrus crispus*, *Phyllophora* spp., and *Laminaria* spp.), and an abundance of smaller ephemeral and epiphytic species (*Chondria tenuissima*, *Lomentaria orchadensis*, *Callithamnion* spp., and *Giffordia granulosa*). The scarcity of benthic macrophytic species reflected on an inability to successfully compete for space against the extensive mussel populations.

The ephemeral and epiphytic species, in contrast, were not in direct competition for space with the mussels, and their increased numbers resulted from their ability to utilize the mussels themselves as substratum. The algal populations of all stations were also characterized ty relatively high species diversity (a function of the large number of epiphytic and ephemeral species) and low biomass (a reflection of the overall lack of benthic macroscopic species).

Because of the evidence of strong scouring on the ledge and periodic scouring even beyond the 30' isobath, it is obvious that uncontained spoils deposited on Black Ledge would experience rapid dispersal. Any design for dredge spoils disposal in this area should strongly consider total containment within a rock breakwater. In order to approach the one half mile square area mentioned in the RFP for this survey, the rock breakwater would have to be constructed near the 20' isobath. A rock breakwater of this size and length would provide an extremely large area for the re-establishment of a community similar to that which is presently found on Black Ledge. Assuming a square configuration ½ mile on each side, the 20' breakwater would be approximately 10,500' in length. Allowing for a slope on the outer face of 45°, and an increase in colonizable area of 3X due to the numerous crevices between individual stones, the total new area available would be approximately 900,000 square feet. Approximately 50% of the 7×10^6 square feet of area which would be occupied by the proposed DMCF is hard bottom which presently supports *Mytilus* populations. Thus, construction of the DMCF would remove approximately 75% of this community type from the local ecosystem.

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Appendix 1

Report on Results of REMOTS Survey of
Black Ledge, Connecticut

Marine Surveys, Inc.
275 St. John Street
New Haven, CT

Introduction

On August 31, 1981, a REMOTS™ benthic survey was conducted at four of five stations located west and south of the rocky shoal area called Black Ledge at the mouth of New London Harbor. Between 5 and 6 replicate sediment profile images were obtained at each of the four stations. Station locations are as follows (see Clinton Report for format explanation):

STATION DESCRIPTIONS -- BLACK LEDGE

August 31, 1981

STATION BL1
25'
7:50 AM
60° - Tank and Frank Ledge "BRC" lined up
170 yds to "BRC"

STATION BL2
30'
8:30 AM
250 yds NW of can #3
55° to Tank

STATION BL3
39'
9:45 AM
200 yds SW of Nun "4"
48° - Nun "4" to Pine Island tower

STATION BL4
33'
9:05 AM
55° - 62° - Tower on Pine Island
400 yds SW of Nun "6"
due south of New London Light

STATION BL5
35'
10:15 AM
Line up New London Harbor light house with N "2" & N "6"
Line up west side of mansion with water tank (10° N)

Methods

Sediment profile images were measured for: 1) modal grain-size; 2) camera penetration depth; 3) presence of sediment methane; 4) aerated sediment area (positive redox are); and 5) faunal successional stage. Variables 3 - 5 were used to generate a habitat index based on the following scaling:

Planimetered RDP Area	Index Value
0 - $10cm^2$	1
10.1 - $20.0cm^2$	2
20.1 - $30.0cm^2$	3
30.1 - $40.0cm^2$	4
40.1 - $50.0cm^2$	5
$>50.1cm^2$	6

Successional Stage	Index Value
Azoic	-5
Stage 1	1
Stage 1 - 2	2
Stage 2	3
Stage 2 - 3	4

Chemical Parameters	Index Value
Methane present	-2
No/low dissolved O_2	-4

The values for the above parameters are given in Table I.

Results

The dominant grain sizes at stations 1 - 4 fall within the Udden-Wentworth size class of 4 - 2 phi (very fine sand). Stations 1 and 2 were found to be in Stage 1 (polychaete dominated) succession while stations 3 and 4 were in Stage II (amphipod-dominated) succcession (Figure 1). Tube mats of Ampelisca abdita at station 4 were recently scoured and broken up. Photos of this station show abundant evidence of recent bottom erosion. For this reason, we have designated station 4 as being retrograde.

No stations were found to contain evidence of methane gas production at depth, and all stations were covered with aerobic water. The mapped habitat indices are shown in Figure 2. The values are means of the replicate samples and are shown beside each station number. All indices are positive. Stations 1 and 2, located in water depths > 30 feet have indices of 4, while those located in water deeper than 30 feet have indices of 7.

Conclusions

The presence of faunal stages I and II in the region of Black Ledge is a typical pattern of successional mosaics in harbors. The relatively high habitat indices (especially for August) suggest however that these assemblages have not experienced a great deal of pollution. Stage I assemblages in heavily polluted regions of harbors typically have habitat values of 1 - 3.

We can make assumptions about the history of bottom disturbance (current scour) from the mapped successional stages. The mapped indices suggest that those areas located above the 30 foot isobath are more frequently disturbed than areas below this depth. Because we did not observe any Stage III development in the studied area, we might assume that even stations 3 and 4 experience disturbance sometime during the year, causing them to "retrograde". This disturbance is probably related to winter storm wave activity. We suggest than bottom turbulance affects the area of study but that the frequency of disturbance differs between stations. Stations 1 and 2 are more frequently disturbed than stations 3 and 4. The 30-foot isobath may be an important depth contour for defining this disturbance gradient. Uncontained spoils deposited in this region would probably experience dispersal on the time scale of one year. Turbulent mixing probably affects the bottom to depths of at least 40 feet during the winter months.

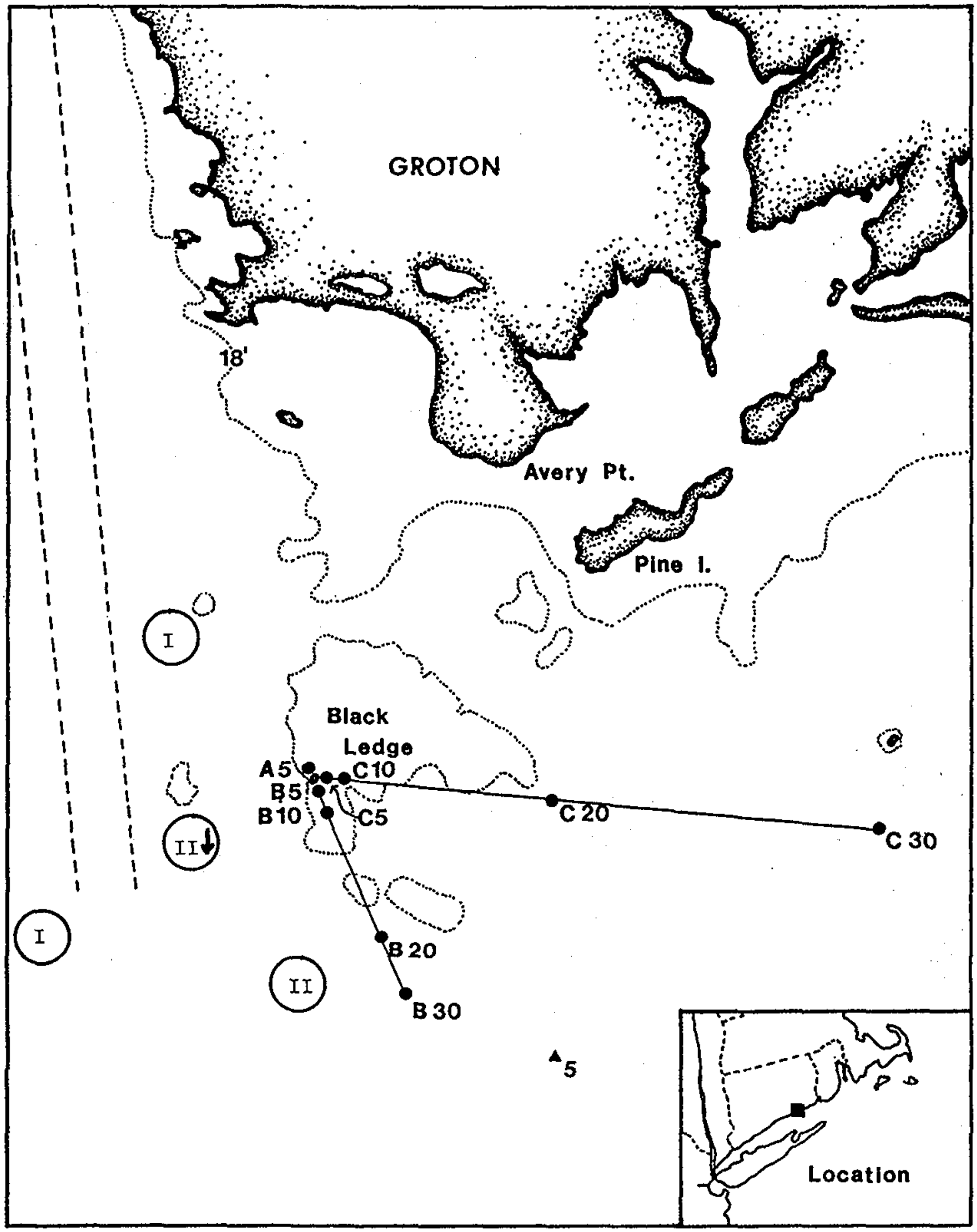

Figure 1: Community successional stages: I = polychaete dominated
II = amphipod dominated.

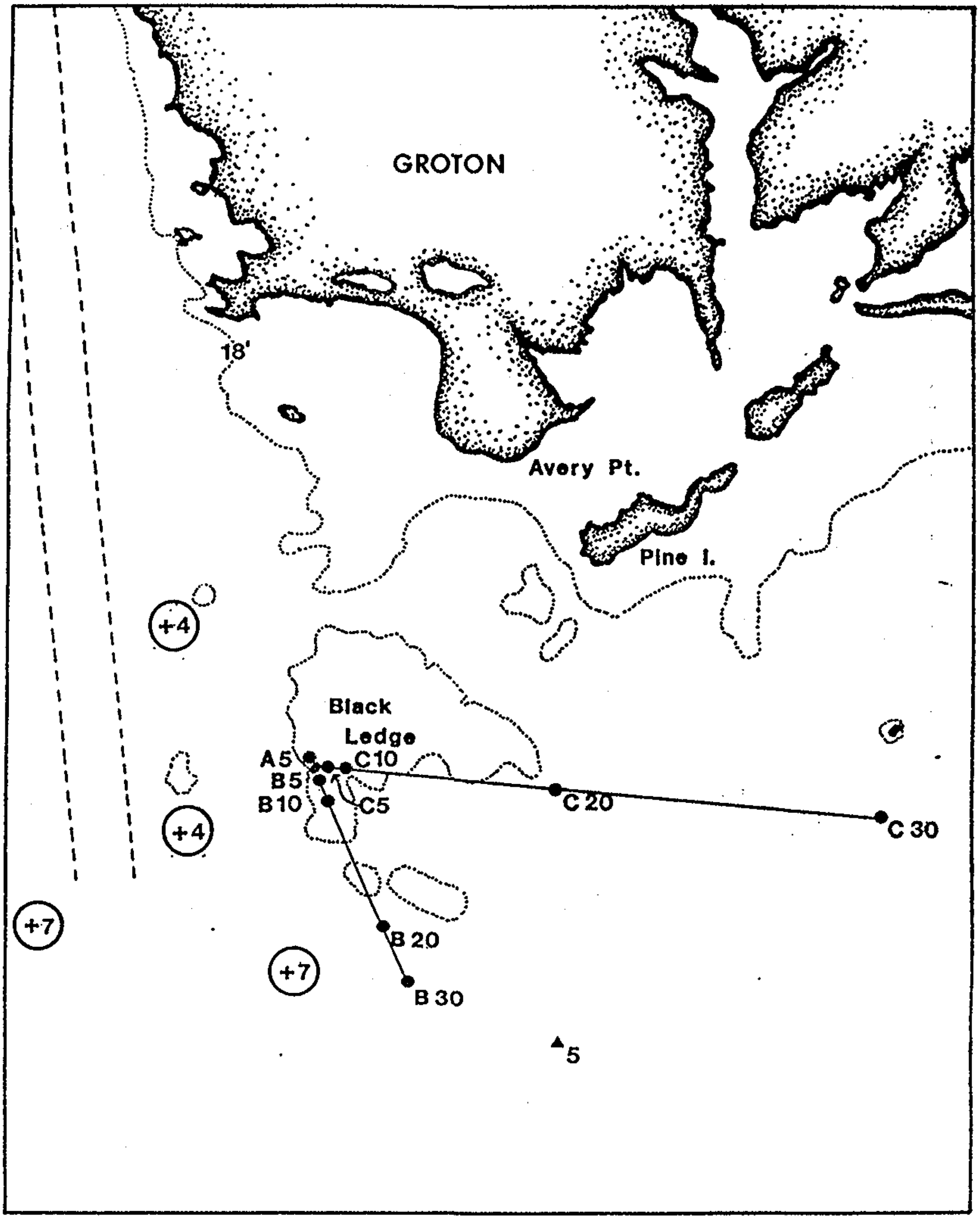

Figure 2: Plot of habitat index scores for four stations at Black Ledge evaluated by REMOTS imagery. Scale ranges from -10 to +10.

Table 1: Scores by station and replicate for parameters used in evaluating imagery obtained by REMOTS photography.

Station	Sediment Type	P	Redox(cm^2)	CH_4	Successional Stage	Habitat Index
1-1	4 - 3Ø	4.6	19.2	no	I	3
1-2	4 - 3Ø	5.1	27.5	no	I	4
1-3	4 - 3Ø	4.6	26.6	no	I	4
1-4	4 - 3Ø	4.6	28.9	no	I	4
1-5	4 - 3Ø	4.8	23.2	no	I	4
2-1	4 - 3Ø	3.9	30.8	no	I	5
2-2	4 - 3Ø	4.3	19.6	no	I	3
2-3	4 - 3Ø	3.5	34.1	no	I	5
2-4	4 - 3Ø	4.2	33.1	no	I	5
2-5	4 - 3Ø	3.9	21.5	no	I	4
2-6	4 - 3Ø	4.8	28.2	no	I	4
3-1	4 - 3Ø	4.0	37.0	no	II	7
3-2	4 - 3Ø	3.9	41.3	no	II	8
3-3	4 - 3Ø	3.9	40.2	no	II	8
3-4	4 - 3Ø	3.9	39.1	no	II	7
3-5	4 - 3Ø	4.0	37.3	no	II	7
4-1	4 - 2Ø	4.1	44.0	no	II	7
4-2	4 - 2Ø	5.2	31.8	no	II	7
4-3	4 - 2Ø	3.0	36.3	no	II	6
4-4	4 - 2Ø	4.2	41.0	no	II	7
4-5	4 - 2Ø	4.8	60.3	no	II	8

Appendix 2

Location Data for All Stations Sampled at
Black Ledge, Connecticut

Location Descriptions for Black Ledge Stations

Station 1:

200 yds. SW of Frank Ledge RB buoy
Range: RB buoy and tank behind Avery Point

Station 2:

250 yds. NW of harbor entrance lighted buoy #3
Range: New London Ledge Light and tank behind Avery Point

Station 3:

200 yds. SW of Black Ledge nun buoy #4
Range: Nun "4" and extreme western end of Pine Island

Station 4:

400 yds. W of Black Ledge nun buoy #6
200 yds. S of New London Ledge Light

Station 5:

700 yds. (approx.) SE of Black Ledge nun buoy #2
Range: Nun "2", Nun "6", and New London Harbor Light
Range: Western end of mansion on Avery Point and tank behind Avery Point

Transect A:

Determined by harbor channel buoy #6 and water tank at Ft. Trumbull.

Transect B:

180° from Transect A, determined by Black Ledge rocks and water tank at Ft. Trumbull.

Transect C:

Determined by Black Ledge Rocks and New London Ledge Light.

Appendix 3

Sediment Grain-Size Analysis Raw Data

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S1 R1

GRAVEL ______ % MEDIAN .017 mm. CLASSIFICATION ______

SAND ______ % P ______ mm. σ ______

SILT ______ % P ______ mm. Sk. ______

CLAY ______ % DISPERSING AGENT WEIGHT ______ gms./50 ml.

ANALYSIS BY ______ Qd ______ ø DATE 18 Feb 82

C7

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				84	29.4148 / 29.4129			.0019	.02	.02
SAND	2.000 1.000	-1				29.4194			0046	.05	.07
SAND	1.000 .500	0				29.4314			0120	.14	.21
SAND	.500 .250	1				29.4516			0202	.23	.44
SAND	.250 .125	2				29.5120			0604	.69	1.13
SAND	.125 .062	3				31.2121			1.7001	19.29	20.42
	< .062	4				31.4903			2782		
	> .062							12.0142			
SILT	.062 TO .031	4	25 cm.	0 00	55	27.1356 / 26.8422	2934	11.7360	5.4782	62.16	82.58
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	109	27.9759 / 27.8125	1634	6.5360	1.536	17.43	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 1.7992

WT. FINE 7.0142

WT. TOTAL SAMPLE 8.8134

79.59

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S1 R2

GRAVEL ______ % MEDIAN .027 mm. CLASSIFICATION ______

SAND ______ % P ______ mm. σ ______

SILT ______ % P ______ mm. Sk. ______

CLAY ______ % DISPERSING AGENT WEIGHT ______ gms./50 ml.

ANALYSIS BY ______ Qd ______ Ø DATE 18 Jul 82

C8

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				161	29.0109 / 28.9578			.0531	.44	.44
SAND	2.000 1.000	-1				29.0617			.0508	.42	.86
SAND	1.000 .500	0				29.1194			.0577	.47	1.33
SAND	.500 .250	1				29.1807			.0613	.50	1.83
SAND	.250 .125	2				29.2998			.1191	.98	2.81
SAND	.125 .062	3				33.0000			3.7002	30.42	33.23
	< .062	4				33.5209			.5209		
	> .062							13.1209			
SILT	.062 TO .031	4	25 cm.	0 00	152	29.7825 / 29.4675	3150	126000	6.7649	55.62	88.85
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	169	28.7878 / 28.6289	1589	63560	1.356	11.15	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 500

WT. COARSE 4.0422

WT. FINE 8.1209

WT. TOTAL SAMPLE 12.1631

66.77

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge | SAMPLE NO. BL S2 R1

GRAVEL ______ % | MEDIAN 0.031 mm. | CLASSIFICATION ______

SAND ______ % | P ______ mm. | σ ______

SILT ______ % | P ______ mm. | Sk. ______

CLAY ______ % | DISPERSING AGENT WEIGHT ______ gms./50 ml.

ANALYSIS BY ______ | Qd ______ ø | DATE 18 Feb 82

C5

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				220	31.4412 / 31.4340			.0072	.05	.05
SAND	2.000 1.000	-1				31.4582			.0170	.12	.17
SAND	1.000 .500	0				31.4815			.0233	.17	.34
SAND	.500 .250	1				31.5229			.0414	.30	.64
SAND	.250 .125	2				31.7161			.1932	1.39	2.03
SAND	.125 .062	3				36.6276			4.9115	35.29	37.32
	< .062	4				37.0318			.4042		
	> .062					36.4870		137242			
SILT	.062 TO .031	4	25 cm.	0 00	179	36.1540	.3330	13 3300	6.8522	49.23	86 55
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	77	37 6852 / 37.5134	.1718	6.8720	1.872	13.45	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 | 5 00

WT. COARSE 5.1936

WT. FINE 8.7242

WT. TOTAL SAMPLE 13.9178

62.68

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S2 R2

GRAVEL ________ % MEDIAN 0.025 mm. CLASSIFICATION ________

SAND ________ % P ________ mm. σ ________

SILT ________ % P ________ mm. Sk. ________

CLAY ________ % DISPERSING AGENT WEIGHT ________ gms./50 ml.

ANALYSIS BY ________ Qd ________ ø DATE 19 Feb 82

a1

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				94	26.5627 / 26.5627			.0000	0.00	0.00
SAND	2.000 1.000	-1				26.5751			.0124	.11	0.11
SAND	1.000 .500	0				26.5952			.0201	.18	0.29
SAND	.500 .250	1				26.6222			.0270	.24	0.53
SAND	.250 .125	2				26.7548			.1326	1.17	1.70
SAND	.125 .062	3				30.1134			3.3586	29.64	31.34
	< .062	4				30.5169			.4035		
	> .062							12.7795			
		4	25 cm.	0 00	93	28.2625 / 27.9531	.3094	12.3760			
SILT	.062 TO .031								6.3315	55.88	87.22
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
		8	10 cm.	2 08	31	28.1898 / 28.0286	.1612	6.4480			
CLAY	.004 TO .002								1.448	12.78	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 — 5.00

WT. COARSE 3.5507

WT. FINE 7.7795

WT. TOTAL SAMPLE 11.3302

68.66

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S3 R1

GRAVEL ____ % MEDIAN 0.021 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ Ø DATE 18 Feb 82

C1

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				189	27.0221 / 27.0221			.0000	0.00	0.00
SAND	2.000 1.000	-1				27.0275			.0054	.05	.05
SAND	1.000 .500	0				27.0394			.0119	.11	.16
SAND	.500 .250	1				27.0683			.0289	.26	.42
SAND	.250 .125	2				27.2205			.1522	1.39	1.81
SAND	.125 .062	3				30.1460			2.9255	26.65	28.46
	< .062	4				30.3303			.1843		
	> .062							12.8523			
SILT	.062 TO .031	4	25 cm.	0 00	51	27.3836 / 27.0669	3167	12.6680	5.9603	54.30	82.76
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	106	28.5181 / 28.3458	1723	6.8920	1.8922	17.24	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 3.1239

WT. FINE 7.8523

WT. TOTAL SAMPLE 10.9762

71.54

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S3 R2

GRAVEL ______ % MEDIAN 0.021 mm. CLASSIFICATION ______

SAND ______ % P ______ mm. σ ______

SILT ______ % P ______ mm. Sk. ______

CLAY ______ % DISPERSING AGENT WEIGHT ______ gms./50 ml.

ANALYSIS BY ______ Qd ______ ø DATE 18 Feb 82

Cb

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				27	27.0434 / 27.0434			0000	0 00	0 00
SAND	2.000 1.000	-1				27.0591			.0157	.11	.11
SAND	1.000 .500	0				27.0903			.0312	.21	.32
SAND	.500 .250	1				27.1646			.0743	.50	.82
SAND	.250 .125	2				27.4051			.2405	1.62	2 44
SAND	.125 .062	3				31.3725			3.9674	26.68	29.12
	< .062	4				31.7473			.3748		
	> .062							15.5388			
SILT	.062 TO .031	4	25 cm.	0 00	149	26.7472 / 26.3681	.3791	15.1640	7.9508	53.48	82.60
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	204	29.2649 / 29.0752	.1897	7.5880	2.588	17.41	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5 00

WT. COARSE 4.3291

WT. FINE 10.5388

WT. TOTAL SAMPLE 14.8679

70.29

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge　　SAMPLE NO. BL S4 R1

GRAVEL ____ %　　MEDIAN .018 mm.　　CLASSIFICATION ____

SAND ____ %　　P ____ mm.　　σ ____

SILT ____ %　　P ____ mm.　　Sk. ____

CLAY ____ %　　DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____　　Qd ____ ø　　DATE 18 Feb 82

C4

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				184	28.1760 / 28.1760			.0000	0.00	0.00
		-1									
SAND	2.000 1.000					28.1930			0170	0.12	0.12
		0									
SAND	1.000 .500					28.2275			0345	0.24	0.36
		1									
SAND	.500 .250					28.2749			0474	0.33	0.69
		2									
SAND	.250 .125					28.3605			0856	0.59	1.28
		3									
SAND	.125 .062					31.2879			2.9274	20.12	21.40
		4									
	< .062					31.5460			2851		
	> .062					31.2908		16.4371			
SILT	.062 TO .031	4	25 cm.	0 00	226	28.8870	4028	16.1520	9.0971	62.53	83.93
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32		28.0210					
CLAY	.004 TO .002	8	10 cm.	2 08	87	27.8375	1835	7.3400	2.34	16.08	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20　　5.60

WT. COARSE 3.1119

WT. FINE 11.4371

WT. TOTAL SAMPLE 14.5490

78.61

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S4 R2

GRAVEL ____ % MEDIAN .022 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ Ø DATE 18 Feb 82

C2

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 × WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				68	26.2572 / 26.2563			.0009	0.00	0.00
SAND	2.000 1.000	-1				26.2676			.0104	0.07	0.07
SAND	1.000 .500	0				26.3124			.0448	0.31	0.38
SAND	.500 .250	1				26.3975			.0851	0.58	0.96
SAND	.250 .125	2				26.7483			.3508	2.40	3.36
SAND	.125 .062	3				30.3937			3.6454	24.92	28.28
	< .062	4				30.6071			.2134		
	> .062							15.4894			
SILT	.062 TO .031	4	25 cm.	0 00	99	29.6670 / 29.2851	.3819	15.2760	8.2934	56.70	84.98
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	19	27.0132 / 26.8333	.1799	7.1960	2.196	15.01	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT × 20: 5.00

WT. COARSE 4.1374

WT. FINE 10.4814

WT. TOTAL SAMPLE 14.6268

71.71

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge | SAMPLE NO. BL S5 R1
GRAVEL ______ % | MEDIAN .074 mm. | CLASSIFICATION ______
SAND ______ % | P ______ mm. | σ ______
SILT ______ % | P ______ mm. | Sk. ______
CLAY ______ % | DISPERSING AGENT WEIGHT ______ gms./50 ml.
ANALYSIS BY ______ | Qd ______ Ø | DATE 18 Feb 82

C3

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				108	27.1850 / 27.0202			1648	.85	.85
SAND	2.000 1.000	-1				27.2731			.0881	.45	1.30
	1.000 .500	0				27.5682			.2951	1.52	2.82
	.500 .250	1				28.2665			.6983	3.61	6.43
	.250 .125	2				29.6485			1.3820	7.14	13.57
	.125 .062	3				39.0666			9.4181	48.63	62.20
	< .062	4				39.5025			4369		
	> .062							12.2209			
SILT	.062 TO .031	4	25 cm.	0 00	165	31.9184 / 31.6213	2971	11.8840	5.5209	28.51	90.71
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	13	26.3116 / 26.1416	1700	6.800	1.800	9.29	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00
WT. COARSE 12.0464
WT. FINE 7.3209
WT. TOTAL SAMPLE 19.3673

37.8

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S5 R2

GRAVEL ______ % MEDIAN .068 mm. CLASSIFICATION ______

SAND ______ % P ______ mm. σ ______

SILT ______ % P ______ mm. Sk. ______

CLAY ______ % DISPERSING AGENT WEIGHT ______ gms./50 ml.

ANALYSIS BY ______ Qd ______ ø DATE 19 Feb 82

92

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				97	25.3019 / 25.3019			0.00	0.00	0.00
		−1									
SAND	2.000 1.000					25.3266			.0247	0.20	0.20
		0									
SAND	1.000 .500					25.4758			.1492	1.24	1.44
		1									
SAND	.500 .250					25.7927			.3169	2.63	4.07
		2									
SAND	.250 .125					26.3706			.5779	4.79	8.86
		3									
SAND	.125 .062					32.0216			5.6510	46.86	55.72
		4									
	< .062					32.4094			.3878		
	> .062							10.3398			
		4	25 cm.	0 00	208	30.4179 / 30.1691	.2488	9.9520			
SILT	.062 TO .031								3.8918	32.27	87.99
		5	10 cm.	0 02							
SILT	.031 TO .016										
		6	10 cm.	0 08							
SILT	.016 TO .008										
		7	10 cm.	0 32							
SILT	.008 TO .004										
		8	10 cm.	2 08	17	28.7230 / 28.5618	.1612	6.4480			
CLAY	.004 TO .002								1.448	12.01	100
		9	7 cm.	5 58							
CLAY	.002 TO .001										
		10	7 cm.	24 00							
	< .001										

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 6.7197

WT. FINE 5.3348

WT. TOTAL SAMPLE 12.0595

44.28

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL C30 R1
GRAVEL ______ % MEDIAN .136 mm. CLASSIFICATION ______
SAND ______ % P ______ mm. σ ______
SILT ______ % P ______ mm. Sk. ______
CLAY ______ % DISPERSING AGENT WEIGHT ______ gms./50 ml.
ANALYSIS BY ______ Qd ______ ø DATE 19 Feb 82

a3

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 × WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				28	27.2989 / 26.8956			.4033	1.97	1.97
SAND	2.000 1.000	-1				28.0312			.7323	3.57	5.54
SAND	1.000 .500	0				30.7229			2.6917	13.14	18.68
SAND	.500 .250	1				25.4883			4.7654	23.26	41.94
SAND	.250 .125	2				37.3796			1.8913	9.23	51.17
SAND	.125 .062	3				44.4070			7.0274	34.30	85.47
	< .062	4				44.7339			.3269		
	> .062							7.9749			
SILT	.062 TO .031	4	25 cm.	0 00	191	30.7406 / 30.5494	.1912	7.6480	2.3149	11.30	96.77
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	203	28.2373 / 28.0958	.1415	5.6600	0.66	3.22	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT × 20 5.00
WT. COARSE 17.5114
WT. FINE 2.9749
WT. TOTAL SAMPLE 20.4863

14.52

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL C30 R2
GRAVEL ______ % MEDIAN .327 mm. CLASSIFICATION ______
SAND ______ % P ______ mm. σ ______
SILT ______ % P ______ mm. Sk. ______
CLAY ______ % DISPERSING AGENT WEIGHT ______ gms./50 ml.
ANALYSIS BY ______ Qd ______ Ø DATE 19 Feb 82

a4

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				160	30.8393 / 29.8621			.9772	5.96	5.96
		-1									
SAND	2.000 1.000					31.9971			1.1578	7.06	13.02
		0									
SAND	1.000 .500					35.3033			3.3062	20.16	33.18
		1									
SAND	.500 .250					39.8158			4.5125	27.51	60.69
		2									
SAND	.250 .125					41.0637			1.2479	7.61	68.30
		3									
SAND	.125 .062					44.7431			3.6794	22.43	90.73
		4									
	< .062					44.8596			.1165		
	> .062							6.5205			
		4	25 cm.	0 00	39	29.7345 / 29.5744	.1601	6.4040			
SILT	.062 TO .031								1.3165	8.03	98.76
		5	10 cm.	0 02							
SILT	.031 TO .016										
		6	10 cm.	0 08							
SILT	.016 TO .008										
		7	10 cm.	0 32							
SILT	.008 TO .004										
		8	10 cm.	2 08	3	24.8403 / 24.7102	.1301	5.2040			
CLAY	.004 TO .002								0.204	1.24	100
		9	7 cm.	5 58							
CLAY	.002 TO .001										
		10	7 cm.	24 00							
	< .001										

WEIGHT DISPERSING AGENT x 20 — 5.00
WT. COARSE 14.8810
WT. FINE 1.5205
WT. TOTAL SAMPLE 16.4015

9.27

ARTIFACTS:

Appendix 4

Macrofaunal Analysis Raw Data

Note:

Counts for grab samples per $0.04m^2$, counts for diver-collected samples per $0.11m^2$ (see text).

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
POLYCHAETA																
Aglaophamus neotenus																
Ampharete arctica																
Ampharetidae unid.				1	11	1	3							2		
Amphecteis gunneri						1		1								
Amphitrite johnstoni																
Amphitrite sp.														2	2	
Anaitides mucosa					32	21	9	9	6	21						
Anaitides sp.	2															
Aricidea sp.	824	1291	429	638		1	11	3	9	18						
Asabellides oculata	1								1	3						
Autolytus sp.																
Capitella captitata											17		2		12	6
Cirratulus sp.															2	
Clymenella torquata	21	4	6	6	2	2	8	10	4	7						
Cossura longocirrata		25	3	3				1								
Disoma carica					2											
Dorvilleidae unid.											1					
Drilonereis longa																
Drilonereis magna									1							
Ephesiella minuta																
Euchone sp.					1		2		2	1						
Eulalia viridis																
Eumida sanguinea																
Eunicea unid.																
Exogone sp.								1	2		1				20	
Glycera americana																
Harmothoe imbricata					1		1		1		40	24	32	22	32	12
Lepidonotus squamatus												6	4	6	3	12
Lepidonotus sublevis																
Lumbrineris sp.	2	2	10		22	21	34	30	1	16						
Maldanopsis elongata	2	1	3	3					2							
Marphysa sanguinea											2	6	4	6	4	
Mediomastus ambiseta	36	44	79	101	17	3	27	9	25	55						

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
Melinna cristata										20						
Nephtys incisa	24	22	19	30	14	24	23	36	7	11						
Nephtys picta																
Nereis arenaceodonta																
Nereis pelagica												2				4
Nereis succinea																
Nereis virens												2				
Nicolea venustula																
Ninoe nigripes	24	4	1	1	3		2		1	1						
Notomastus sp.																
Oligochaeta	6	1	7	4	3	1	4	1	1	19	8	8	2	6	24	
Onuphis quadricuspis							1	1		2						
Orbiniidae unid.																
Paraonis fulgens							1									
Paraonis sp.			2		2	2		1	1	1						
Parapionosyllis longicirrata											6					
Pectinaria gouldii											1					
Pherusa affinis									1	1						
Pholoe minuta	7		1	2	4	9	2	5	3	7						
Phyllodocidae unid.																
Pista palmata																
Polycirrus eximius	18		5	2	2	3	15	7	15		3	2		14	4	6
Polydora socialis	1															
Polydora sp.						1										
Polygordius sp.																
Potamilla neglecta																
Potamilla reniformis											1					
Prionospio cirrifera	2	1		3	2	1	3	1	8	1						
Pygospio elegans							2									
Sabellaria vulgaris																
Scalibregma inflatum									1							
Scolelepis squamata			1	2												
Scoloplos acutus	71	18	4	1	4	2	5	4	2	3						
Sigambra tentaculata	1		1	5	2	2		1		3						

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
Sphaerosyllis sp.											2					
Spiochaetopterus oculatus					1				1	5						
Spionidae unid.																
Spiophanes bombyx	1								2							
Sthenelais boa																
Sthenelais limicola			1													
Streblospio benedicti	1	2		2												
Syllinae/Eusyllinae unid.												2			2	
Tharyx acutus	69	72	14	35	17	10	13	16	23	28	9	10				
GASTROPODA																
Acteocina canaliculata										4						
Alvania sp.											1				2	
Anachis avara											41	22	20	4	77	6
Buccinium sp.															2	
Busycon canaliculatum											1				2	
Cingula aculeus											3				12	
Colus obesa																
Crassinella lunulata																
Crepidula fornicata													12			
Crepidula plana											14	2			2	4
Cylichna oryza	1				4	1	1	1								
Epitonium humphreysi											1					
Lacuna vincta													2		2	
Lunatia heros			1							1						
Lunatia triseriata									1						2	
Mitrella dissimilis																
Mitrella lunata					39	23	6	27		11	134	36	234	46	260	26
Nassarius trivittatus					1	2		1			3			8		
Odostomia gibbosa											2					
Odostomis seminuda																
Philine lima																
Skeneopis planorbis																
Turbonilla sp.				2	10			4		2		6			14	2
Urosalpinx cinerea												2				

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
BIVALVIA																
Astarte undata					4		1	2	6	5						
Bivalvia unid.																
Cerastoderma pinnulatum	1						1			1						
Crenella glandula																
Cumingia tellinoides																
Cyclocardium borealis					5	3			2	10						
Ensis directus					1				1							
Lyonsia hyalina					6	1	3	6		1						
Macoma balthica	1	1														
Mercenaria mercenaria			1						1							
Modiolus modiolus											2					
Mulinia lateralis	1															
Mytilus edulis											324	423	723	361	777	582
Nucula delphinodonta	2	6		8	35	19	3	25	1	4	1					
Nucula proxima	45	243	143	209	42	48	10	74	1	7	2	2	6	2	6	2
Petricola pholadiformis						1										
Pitar morrhuanus						1										
Solemya velum								1								
Tellina agilis		2			2			1	2						2	
Thracia conradi						1			2							
Yoldia limatula	2		2		1		1	2	1	1						
AMPHIPODA																
Ampelisca abdita	8	9	4	2	949	909	979	833	2421	2072						
Ampelisca vadorum														2		
Ampelisca verrilli																
Amphithoe longimana											8		4		6	2
Byblis serrata																
Caprellidae unid.										1	3		4		10	2
Corophium acutum											4	2	2	2	12	
Corophium bonelli					12	3	1	1	22	26	3					
Dexamine thea											10	8	4	8	12	10
Elasmopus levis													2		4	
Erichthonius rubricornis					14	5	10	19	4	5						

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
Jassa falcata											8		2	4	8	18
Lembos websteri											8	10	8	4	44	2
Leptocheirus pinguis	4			1	3	10		3	5	1						
Lysianopsis alba												8	2	2		
Microdeutopus gryllotalpa															2	
Paraphoxus spinosus															2	2
Photis sp.					1	3	3	3								
Phoxocephalus holbolli												2			2	
Pleusymtes glaber																
Stenothoe minuta																
Trichophoxus epistomus											3					
Unciola irrorata			5	2	8	7	4	1	16	30						
CRUSTACEA																
Campylaspis rubicunda																
Cancer borealis											1					
Cancer irroratus														2		
Crangon septemspinosa																
Cylindroleberis mariae																
Cythereis vineyardensis																
Edotea triloba					5	3	4	1								
Erichsonella filiformis											8		2		6	
Eudorella pusilla							1	1								
Heteromysis formosa																
Idotea phosphorea													2		2	2
Iphinoe trispinosa																
Leptochelia savignyi																
Libinia dubia										1	2					
Libinia sp.																
Mysidacea unid.																
Neopanope sayi											2	2		4	2	
Ostracoda unid.	3			1	7	2		5		9						
Oxyurostylis smithi							1									
Pagurus longicarpus					1											
Pinnotheres maculatus											5		4		2	4

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
Ptilanthura tenuis	1															
Pycnogonida unid.											1					
Sarsiella sp.	27		1		22	2	25	11		7	1				12	
Upogebia affinis																
MISCELLANEOUS																
Amphipholis squamata											47	36	24	56	138	2
Arbacia sp.														2		
Asterias forbesi															2	
Cerebratulus sp.							1									
Cerianthus sp.		1														
Edwardsia sp.	2	3		1												
Enteropneusta unid.					2											
Henricia sanguinolenta											1					2
Metridium senile											14	28	30	22	10	30
Nemertea unid.	3								1	1						
Phoronida unid.	2															
Sipuncula unid.						2		2								
Tubulanus pellucidus			1	3												

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
POLYCHAETA												
Aglaophamus neotenus												1
Ampharete arctica											1	
Ampharetidae unid.	3	1	3	4					1			
Amphecteis gunneri												
Amphitrite johnstoni						2						
Amphitrite sp.												
Anaitides mucosa	1	1	1	2							4	3
Anaitides sp.												
Aricidea sp.	29	21	2	2					6	20	14	4
Asabellides oculata										2		
Autolytus sp.								1				
Capitella captitata	31	45			8	4	8		13	14		
Cirratulus sp.					2							
Clymenella torquata		1									25	35
Cossura longocirrata												
Disoma carica												
Dorvilleidae unid.	13	27		2						36	3	3
Drilonereis longa	3											
Drilonereis magna												
Ephesiella minuta									1			
Euchone sp.												
Eulalia viridis						2						
Eumida sanguinea	4		1	6					14	14		4
Eunicea unid.		1										
Exogone sp.	141	188		88	14				70	96	39	12
Glycera americana		2		2						2	2	1
Harmothoe imbricata	1	1	5	2	24	36	90	18	4			
Lepidonotus squamatus		1			20	6		7	1			
Lepidonotus sublevis				4								
Lumbrineris sp.	3	2	3	102					7	26	2	4
Maldanopsis elongata											1	
Marphysa sanguinea	1				4			11				
Mediomastus ambiseta		1	1								9	21

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
Melinna cristata												
Nephtys incisa			1	2					1	2		
Nephtys picta											8	
Nereis arenaceodonta		3								2		
Nereis pelagica					2			11	4			
Nereis succinea							10					
Nereis virens	1											
Nicolea venustula						2						
Ninoe nigripes	2		1	3		2						
Notomastus sp.	1											
Oligochaeta	99	89	1	27				110	36	76	17	23
Onuphis quadricuspis												
Orbiniidae unid.										2		
Paraonis fulgens												
Paraonis sp.		5										
Parapionosyllis longicirrata		5				10	2			10		
Pectinaria gouldii			1									
Pherusa affinis	1	1										
Pholoe minuta	3		7	4	2			1		4	4	3
Phyllodocidae unid.		34	2									1
Pista palmata			1									
Polycirrus eximius	52	98	23	94				2	32	76	6	12
Polydora socialis												
Polydora sp.		6							2		7	2
Polygordius sp.	45	89							55	132	8	8
Potamilla neglecta						4						
Potamilla reniformis											2	
Prionospio cirrifera												
Pygospio elegans												
Sabellaria vulgaris						2					1	
Scalibregma inflatum		1										
Scolelepis squamata												
Scoloplos acutus												
Sigambra tentaculata				6								

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
Sphaerosyllis sp.												
Spiochaetopterus oculatus												2
Spionidae unid.		1										
Spiophanes bombyx		8								2	70	59
Sthenelais boa				2								
Sthenelais limicola								1				
Streblospio benedicti												
Syllinae/Eusyllinae unid.	4	17	4					1	13	46	3	
Tharyx acutus	11	20	31	170	2	2		4	67	56	40	36
GASTROPODA												
Acteocina canaliculata												
Alvania sp.							2					
Anachis avara	1	2	5		40	10	180	3	3			
Buccinium sp.												
Busycon canaliculatum												
Cingula aculeus								2				
Colus obesa					2							
Crassinella lunulata			1									
Crepidula fornicata		1										
Crepidula plana	3	3		8	14	28	26	2				
Cylichna oryza												
Epitonium humphreysi												
Lacuna vincta	3				2							
Lunatia heros		7										
Lunatia triseriata			1				8	2				
Mitrella dissimilis												1
Mitrella lunata	43	3	7	54	424	154	318	40			1	
Nassarius trivittatus												
Odostomia gibbosa							4					
Odostomis seminuda						2						
Philine lima	2	3	3	9					8			
Skeneopis planorbis				6								
Turbonilla sp.	11	17		14			10					
Urosalpinx cinerea												

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
BIVALVIA												
Astarte undata												
Bivalvia unid.		3				2			2			
Cerastoderma pinnulatum												
Crenella glandula				14								
Cumingia tellinoides							2					
Cyclocardium borealis												
Ensis directus												1
Lyonsia hyalina	2			4					4			1
Macoma balthica	3								1			
Mercenaria mercenaria		1										
Modiolus modiolus							4					
Mulinia lateralis												
Mytilus edulis					1454	490	959	201				
Nucula delphinodonta				2								1
Nucula proxima	1	3	2	5			16	1				1
Petricola pholadiformis												
Pitar morrhuanus												
Solemya velum												
Tellina agilis	2	1	2	4							2	
Thracia conradi												
Yoldia limatula												
AMPHIPODA												
Ampelisca abdita		3	37	2								83
Ampelisca vadorum	1								4	24	57	4
Ampelisca verrilli											16	
Amphithoe longimana						6	10					
Byblis serrata											1	
Caprellidae unid.	30	11	7	6		4		1	20	24		
Corophium acutum		8	25			2			2	4		
Corophium bonelli	2	6	4	4					3			
Dexamine thea		3	2		10	34	10	2				
Elasmopus levis						2						
Erichthonius rubricornis			10	4								

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
Jassa falcata				4	2	16	20					
Lembos websteri	4		18		14	78		4	3	2		
Leptocheirus pinguis	13	22	5	4					10		7	3
Lysianopsis alba	2	1	7				12	20	17	4		
Microdeutopus gryllotalpa								7				
Paraphoxus spinosus	4	12	4					2	30	24		
Photis sp.												
Phoxocephalus holbolli	14	14	2	12					23			
Pleusymtes glaber						4						
Stenothoe minuta						6					3	
Trichophoxus epistomus							2					
Unciola irrorata		6								2	39	66
CRUSTACEA												
Campylaspis rubicunda	1											
Cancer borealis								1				
Cancer irroratus					2			1				
Crangon septemspinosa			1									
Cylindroleberis mariae			1			4						
Cythereis vineyardensis										2		
Edotea triloba												
Erichsonella filiformis	1	1	4	4		2			1	4		
Eudorella pusilla				2								
Heteromysis formosa			18		2			2	1			1
Idotea phosphorea			1			20				8		
Iphinoe trispinosa				2								
Leptochelia savignyi	31	26							79	62		
Libinia dubia	1		2	2								1
Libinia sp.												
Mysidacea unid.		2										
Neopanope sayi		1			6	2	6	5				
Ostracoda unid.			6	52							1	4
Oxyurostylis smithi	11	14	5						1	2		1
Pagurus longicarpus	9	1							6	2		1
Pinnotheres maculatus						2						

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
Ptilanthura tenuis		1	1	2								
Pycnogonida unid.			3	2								
Sarsiella sp.	7	3	72	57					3		2	4
Upogebia affinis												
MISCELLANEOUS												
Amphipholis squamata				2	12	4	24	41	1			
Arbacia sp.												
Asterias forbesi												
Cerebratulus sp.												
Cerianthus sp.												
Edwardsia sp.												
Enteropneusta unid.												
Henricia sanguinolenta	1											
Metridium senile						14	88	1				
Nemertea unid.		1	1	2		2						
Phoronida unid.	1											
Sipuncula unid.		1										
Tubulanus pellucidus												